2012

The use of reconstructed prairies in Iowa's agricultural landscape to increase ecosystem services and move towards multifunctionality

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The use of reconstructed prairies in Iowa's agricultural landscape to increase ecosystem services and move towards multifunctionality

by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Co-majors: Crop Production and Physiology; Wildlife Ecology

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Ames, Iowa

2012

Table of Contents

Thesis Abstract v

Chapter 1. General introduction 1

Introduction and project description 1

Thesis organization 3

References 4

Chapter 2. The impact of reconstructed prairies on aphidophagous predator abundance and predation rates of soybean aphids at the watershed scale 6

Abstract 6

Introduction 8

Materials and methods 12

Results 21

Discussion 25

Acknowledgements 30

References cited 32

Chapter 3. Grazing cattle on reconstructed prairie to balance conservation needs and production goals: a case study in central Iowa, USA 50

Abstract 50

Introduction 52

Ecological considerations 54

Methodology 63

Agronomic data collection 63

Animal nutrition scenarios 66

Economic budgets 67

Results 69

Agronomic and livestock considerations 69

Economic considerations 71

Discussion 72

Balancing agronomics, economics, and ecosystem services 72

Conclusion – moving forward 76

Acknowledgements 77

References 78

Chapter 4. Grazing native plants in Iowa: processes and profiles 98

Abstract 98

Why graze prairies? 99

How can I incorporate prairies into my grazing operation? 100

What are the economic risks and benefits? 101

What are the ecological risks and benefits? 102

What are the agronomic risks and benefits? 103

Profiles: grazing native plants in Iowa 103

Graziers 104

Bob Jackson, Tall Grass Bison, Promise City, Iowa 104

Suzanne Castello and Barney Bahrenfuse, B and B Farms, Grinnell, Iowa 106

Bruce Carney, Maxwell, Iowa 107

Ray Bratsch-Prince, Ames Prairie Cattle Company, Ames, Iowa 108

Land Managers 109

Tolif Hunt, Former Director of Whiterock Conservancy, Coon Rapids, Iowa 109

Loren Lown, Natural Resource Specialist, Polk County Conservation, Granger, Iowa 112

Scott Moats, Director of Stewardship, The Nature Conservancy, Iowa 114

Stan Buman, Agren Inc., Agricultural/Environmental Consultant, Carroll, Iowa.................. 117

Putting it all together – balancing economics and ecology 118

Recommendations for future research in grazing native plants 119

Acknowledgements 120

References 122

Chapter 5. General conclusion 123

Summary of results and implications 123

Acknowledgements 125

Thesis Abstract

The landscape of Iowa is dominated by monoculture production of corn (*Zea mays*) and soybean (*Glycine max*). In order to diversify the landscape and increase ecosystem services while maintaining a productive landscape, this thesis considered two strategies for incorporating and using reconstructed prairie in Iowa agriculture. The first strategy considered was the use of reconstructed prairie buffer strips in soybean fields to attract aphidophagous predators to increase diversity and assist in the control of soybean aphid (*Aphis glycines*). While prairie buffer strips were effective at increasing aphidophagous predator abundance, this did not translate into an increase in biological control of soybean aphids. The second strategy considered the use of reconstructed prairie as a source of forage for grazing operations, to balance production and conservation needs. This topic was studied as a case study at Whiterock Conservancy in Coon Rapids, Iowa. The reconstructed prairies studied provided some but not all of the nutritional requirements of cattle during the grazing season. An economic analysis found that grazing reconstructed prairies was more profitable than purchasing low-quality hay. The majority of grazing systems in Iowa are focused on non-native cool season grasses, however a handful of graziers and land managers include native-plant-based grazing systems in their operation. Based on interviews of graziers and land managers, we found there are multiple economically and ecologically viable options for incorporating native plants into grazing systems.

Chapter 1. General introduction

Introduction and project description

The landscape of Iowa is dominated by chemical-intensive, low-diversity, monocultures of corn (*Zea mays*) and soybean (*Glycine max*), making up 43.5% and 31.8% of the farmland, respectively (NASS 2010). Agricultural production in the United States negatively impacts water, soil, air, wildlife, and human health at a cost of approximately $5.7-16.9 billion per year (Tegtmeier and Duffy 2004). As environmental impacts increasingly affect human society, such as recent flooding events in Iowa and trends showing increases in weather extremes (IPCC 2007), there is increasing interest to study the mitigation of agriculture's environmental impact as well as the opportunity for agriculture to mitigate broader environmental issues.

Ecosystem services are "the benefits that people obtain from ecosystems" (MEA 2005) and can be described in four areas: provisioning, regulating, cultural, and supporting services (MEA 2005). Provisioning services are goods required for sustaining human populations, such as food, fiber, fuel, and fresh water. Regulating services are those that regulate earth's cycles that provide a stable place for humans to live and have access to the goods described above. Regulating cycles include climate cycles, flood control, and water purification. Cultural services include recreation, spiritual connections, and aesthetics. Supporting services are those that provide the basis for all the other services, including primary production and soil formation. Agriculture contributes to, but also can reduce ecosystems ability to provide ecosystem services (Tilman et al. 2002).

Multifunctionality means that an activity has multiple functions or outputs and therefore contributes to multiple objectives (OECD 2001). When applied to agriculture or agricultural landscapes, the term multifunctionality refers to a landscape that continues to produce food and fiber but also produces non-commodities, such as preserved natural resources, biodiversity, and social wellbeing (OECD 2001 and Boody et al. 2005). Multifunctional landscapes balance the need for food and fiber production, with the need to maintain and improve other provisioning services along with cultural, regulating, and supporting services.

The current economy lacks substantial markets for ecosystem services (Kroeger and Casey 2007), thus farmers are not offered an incentive to balance profit from production of agricultural goods with providing society with ecosystem services. Additionally, incentives that do exist often lack expert guidance, appropriate policy, and scientific knowledge to best design landscapes for ecological benefit (Dosskey et al. 2012). Though farmers find some ecosystem services, such as increased soil organic matter, of benefit to themselves, many find other services, such as reduced global warming, of less personal benefit and are therefore less motivated to manage for them (Swinton 2008). To move forward with managing agricultural lands for ecosystem services, many have called for more research addressing how farmers can provide a wide range of ecosystem services and what the services are worth (Swinton 2008). Well-thought incentive structures can be created for ecosystem services but in addition there may be opportunities to provide these services while still operating a highly productive and profitable enterprise.

The objective of this thesis is to study and discuss two alternative routes to increasing ecosystem services and rebuilding a multifunctional landscape in Iowa, while maintaining a productive agricultural landscape. The first alternative considered is incorporating strips of prairie into row crop production fields in order to increase insect-derived ecosystem services while maintaining a highly productive row crop landscape. Taking small amounts of agricultural lands out of production and reconstructing native prairies will diversify the landscape of Iowa, and may have further impacts on beneficial insect diversity and abundance, and therefore control of insect pests. This idea is explored in the context of the soybean aphid (*Aphis glycines*) as the primary cause of economic pest damage in soybean production and the opportunity for increased biological control of the soybean aphid. The prairie strips would also serve other benefits, such as wildlife diversity, plant diversity, and erosion and nutrient run-off reduction, which are topics being considered by other researchers and are not explored in this thesis.

The second route to a multifunctional agriculture considered in this thesis is to graze livestock on pastures of native plants. Grazing native plants offers a highly diverse perennial based landscape that also involves grazing cattle for profit. By balancing the need for economic profitability and food production with conservation goals, grazing livestock on native plants offers an alternative to typical grazing operations. Grassland ecosystems offer a wide range of ecosystem services as compared to those provided by row-crop agriculture, which is often the alternative to grasslands.

Thesis organization

This thesis is arranged into five chapters. The first chapter is a general introduction to the thesis, which explores the topics of ecosystem services and multifunctional agricultural landscapes, the theme that ties together the following three chapters of the thesis. The second chapter, "The impact of reconstructed prairies on aphidophagous predator abundance and predation rates of soybean aphids (*Aphis glycines*) at the watershed scale?" explores the impact of prairie strips on beneficial insect populations and their impact on biological control of soybean aphids. The third chapter, "Grazing cattle on reconstructed prairie to balance conservation needs and production goals: a case study in central Iowa, USA" explores agronomic, economic, and ecological issues related to the use of prairie plants as a forage source for grazing animals. The fourth chapter "Grazing native plants in Iowa: processes and profiles" continues the discussion from the third chapter by including profiles of producers and land managers in Iowa that use native plants in their grazing operations and ties together some of the economic and ecological issues brought up in chapter three with on the ground experiences. The fifth and last chapter, "General Conclusions" readdresses the broad issues of ecosystems services introduced at the beginning of the thesis and explored through each chapter in the thesis from a different perspective. Chapters one, two, four, and five use the same reference formatting, which is the standard of the Journal of Environmental Entomology, to which Chapter 2 will be submitted for publication. Chapter three uses a separate reference formatting style, as it is intended to be submitted for publication in the Journal of Renewable Agriculture and Food Systems and follows the journal's reference formatting.

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Chapter 2. The impact of reconstructed prairies on aphidophagous predator abundance and predation rates of soybean aphids at the watershed scale

Modified from a paper to be submitted to the journal *Environmental Entomology*

Rachael Cox, Matthew O'Neal, Rene Hessel, Lisa Schulte Moore, and Matthew Helmers

Abstract

Reconstruction of prairie around annual crop production may contribute to several ecosystem services, including the biological control of insect pests. An ongoing study at Neal Smith National Wildlife Refuge in Iowa has investigated the contribution of varying amounts and configurations of prairie reconstructions to ecosystem services in small watersheds in a corn-soybean rotation. The treatments include watersheds without prairie, 10% of the land in prairie located at the base of the watershed, and 10 or 20% of the land in prairie buffer strips. During 2009 and 2011 growing seasons, we studied aphidophagous predator abundance and communities in response to treatment and habitat differences using sweep net and yellow sticky card sampling. Predators responded to prairie and soybean habitats differently, whereas they did not respond to treatments with different quantities of prairie. In 2011, we studied predation rates of *Aphis glycines* (Hemiptera: Aphididae), the soybean aphid, in response to prairie treatments using an exclusion cage study and found that different prairie treatments did not have a significant effect on soybean aphid biological control. Also in 2011, an exclusion cage study was implemented to determine if predation of soybean aphids was impacted by proximity to prairie buffer strips; the results concluded that distance from prairie did not impact the rate of biological control. The results of this study suggest that prairie buffer strips serve to increase beneficial insect populations, which may not directly benefit soybean aphid control, but increase general ecosystem services on the landscape.

Key Words: biological control, ecosystem services, habitat manipulation, multifunctional, natural enemies, prairie buffer strips

Introduction

As demands for food, fiber, and fuel increase with a growing and more affluent population, the need for agricultural landscapes to respond to environmental problems and contribute to sustainability has become a prominent discussion (von Braun 2007, Godfray et al. 2010, and Tilman et al. 2011). The primary objective of agricultural landscapes may be to produce food, fiber, or fuel; however, these lands could provide multiple benefits to society such as diversity, soil and water quality, air quality, rural viability, and food security (OECD 2001). Multifunctional landscapes can provide agricultural goods and ecosystem services, goods or services that are valued by human society. Multifunctional landscapes can improve ecosystem services and maintain or increase net farm income (Boody et al. 2005).

Reconstruction of native plant communities (i.e. tallgrass prairie in Iowa) around and in annual crop production systems can deliver ecosystem services, whether to improve water quality, increase carbon sequestration, or to create habitat for upland game birds (Lee et al. 1999, Gebhart et al. 1994, George et al. 1979). Restoring tall grass prairie in the agricultural landscape of Iowa is a proposed strategy for increasing ecosystem services, including biological control of insect pests.

The amount and configuration of perennial vegetation may affect the delivery of ecosystem services to crop production. For example, specific vegetation types, such as forest, and their configuration influence the corresponding natural enemy community composition and the amount of biological control of soybean aphids (Gardiner et al. 2009a, Gardiner et al. 2009b). A meta-analysis of insect habitat structure found that an increase in habitat structural complexity, such as through no-tillage, intercropping, or polyculture, corresponded with an increase in natural enemy abundance (Langellotto and Denno 2004).

Aphis glycines Matsumaura (Hemiptera: Aphididae; soybean aphid) is the primary insect pest of soybeans (*Glycine max*) in Iowa and across North America (Ragsdale et al. 2011). The soybean aphid and its host plants, the soybean and common buckthorn (*Rhamnus cathartica)*, are native to Asia, and the soybean aphid was initially found in North America in 2000 (Ragsdale et al. 2011). Current management of the soybean aphid involves scouting and applying foliar insecticides when economic thresholds are reached (Ragsdale et al. 2011); however, calendar date or plant growth stage spraying, especially in mixtures with fungicides, is being marketed and implemented (Johnson et al. 2009).

A diverse mixture of 57 taxa of predators and parasitoids are documented for attacking soybean aphids in the United States (as compiled in Ragsdale et al. 2011). From natural enemy populations in Michigan, Indiana and Iowa, 18 species or life stages have been identified, consisting primarily of predators (Rutledge et al. 2004, Schmidt et al. 2008). Though soybean aphid parasitoids are present in North America, they are a minor component of the natural enemy community (Ragsdale et al. 2011); however, efforts have been made to investigate potential for importation or classical biological control with exotic parasitoids (Heimpel et al. 2004))

The loss and fragmentation of non-crop vegetation, primarily prairie, forest, oak-savanna, and wetland, from the landscape in Iowa may have negatively affected biological control of insect pests (Kruess and Tscharntke 1994) like the soybean aphid (Gardiner et al. 2009a). Key predators of soybean aphids, such as the exotic ladybird beetles *Harmonia axyridis* and *Coccinella septempunctata* respond positively to the presence of forested areas within a landscape (Gardiner et al. 2009b). Efforts to improve soybean aphid biological control by providing habitat for natural enemies has had mixed results (Schmidt et al. 2007, Fox and Landis 2003). These efforts have used general approaches (living mulches, non-crop habitat) that have been shown to improve biological control of other insect pests, but were not necessarily optimized for the needs of the natural enemies of soybean aphids.

Fiedler and Landis (2007) identified a set of native plants that are highly attractive to arthropod natural enemies and provide a flowering resource throughout the season. The results of this research suggest that certain native plants are more attractive to beneficial insects and the attractiveness varies through the season, which in a mixture can provide season long, highly attractive habitat for natural enemies. In this study, many of the native plants surveyed were as or more attractive than exotic annuals that are common in conservation biological control. Native plants are thought to be ideal for providing habitat because they are adapted to environmental conditions of an area and are less likely to become invasive (Frank et al. 2008). Negative aspects of using native plants, especially perennials, for biological control are the longer establishment period and costly or unavailable seed (Isaacs et al. 2008).

Non-crop habitat, such as flowering refuges, may contain an abundant and diverse community of arthropod natural enemies by providing alternative food resources and shelter (Landis et al 2000), increasing the available habitat, however, may or may not translate into a measurable impact on nearby cropland (Woltz et al. 2012). Some studies concluded that nearby non-crop habitat correlates with increasing predation and reduced pest problems. In a study of beetle banks in wheat (*Triticum aestivum*) fields, Collins et al. (2002) observed an interaction between distance from beetle bank and date, with lowest aphid populations eight meters from beetle banks and highest aphid populations 83 meters from banks during peak population. In the United Kingdom, flowering field boundaries have been shown to increase predator abundance in crop fields and decrease aphid populations relative to controls (Hickman and Written 1996).

Similar studies also found that, though natural enemies or pollinators were more abundant in non-crop habitat, the different insect community did not translate to an increase in insect-derived ecosystem services or insect community in the surrounding agricultural area. In the Netherlands, more bees and hover flies were observed in flower-rich patches, but there was no impact of these patches on pollinator abundance or density in the surrounding agricultural fields (Kohler et al. 2008). In Michigan, refuge strips of perennial flowering plants did not have significant effect on the number of beneficial beetles in the adjacent cropland, despite higher beetle activity-density in the strips (Carmona and Landis 1999).

Habitat manipulation for biological control of soybean aphid presents an opportunity to create a multifunctional landscape, one that not only continues to be highly productive of agricultural crops, but also addresses many of the environmental issues caused by crop production. Fiedler et al. (2008) propose that plot and field-level habitat management practices could be designed to provide biological control as well as contribute to soil formation, soil and water conservation, aesthetically improved rural areas, and biodiversity conservation.

A demonstrated increase in natural enemies in prairie buffer strips may not necessarily correspond to an increase in biological control of pests in the adjacent crop. The aim of this study was to determine if the presence of prairie buffer strips within soybean fields will increase this insect-derived ecosystem service. We tested a series of hypotheses that first addressed the effect of prairie buffer strips on soybean aphid predator communities. We hypothesized that 1) more soybean aphid predators will be found in prairie buffer strips than adjacent crop areas and 2) soybean aphid predator abundance and community composition will differ in cropped portions of watersheds consisting of varying amounts and configurations of prairie. A further three hypotheses relate to soybean aphid predation rates within the adjacent cropland. We hypothesized that 3) more aphids will be found in the exclusion cage plants than the open plants due to baseline levels of biological control and successful exclusion of predators, 4) predation rates will vary between watersheds with different prairie treatments, increasing with the percent of land area dedicated to prairie buffer strips within the watershed (i.e. a watershed-scale study), and 5) predation rates will increase with proximity to prairie edge (i.e. a transect study).

Materials and methods

Experimental design. In 2007 a research study was established at the Neal Smith National Wildlife Refuge (NSNWR) in Prairie City, IA to study the many potential ecosystem services available from reconstructed prairie buffer strips within crop fields, including 1) reduced erosion, 2) water quality, 3) carbon and nitrogen cycling, 4) plant diversity, 5) grassland bird habitat, 6) arthropod pollinators, and 7) arthropod natural enemies. The trial is called the strategic Trials of Row crops Integrated with Prairies, or STRIPS. Our overarching hypothesis is that the placement of perennial plant communities at strategic locations and of appropriate spatial extent in a watershed will produce disproportionate improvements in ecosystem functioning without compromising the social and economic viability of agroecosystems (Schulte-Moore and Krogman 2011).

We tested the hypothesis that the amount and configuration of prairie will affect the biodiversity and delivery of ecosystem services to soybeans grown in individual watersheds. The experimental units consisted of watersheds that ranged in size from 0.47 hectares to 3.19 hectares, with slopes ranging from 6.1% to 10.5%. The watersheds were managed for production of corn (*Zea mays*) and soybeans (*Glycine max*) in a rotation that began with soybean in 2009. Crops were produced using conventional practices consistent with the region, including no-till and artificial fertilizers. Pesticides were limited to herbicides (glyphosate); insecticides were not used during either the corn and soybean phase of the rotation. Each watershed received one of four treatments: 1) All crop production, 2) 10% of the watershed dedicated to prairie located at the base of the watershed with the remaining land in crop production, 3) 10% of the watershed dedicated to prairie distributed throughout the watershed, and 4) 20% of the watershed dedicated to prairie distributed throughout the watershed (Figure 1 and Table 1). These treatments were assigned to watersheds within a randomized incomplete block design, with three blocks: two made up of three watersheds, and one made up of six watersheds.

Plant community. In July of 2007 prairie vegetation was established in strips within small watersheds that were planted to soybeans. A seed mixture of 32 species was planted and buffer strips were mowed in 2008 and 2009 for weed management. The seed mixture was selected from other established prairies at Neal Smith National Wildlife Refuge. Sarah Hirsch and others surveyed the plant community on 5-26 July 2011, following the methods outlined in Hirsch (2012). Data reported is on basis of relative ground cover, which was calculated as a percent of total ground cover, dividing ground cover of an individual species by the total percentage of ground cover that was over 100%.

If a plant species accounted for greater than 1% of ground cover, a literature review was conducted to determine relevance to insect natural enemies by searching "natural enemy" OR "beneficial insect"' and refining this search with each plant species name in Web of Science (Thomson Reuters 2011). This potential importance of a plant species for attracting or supporting beneficial insects is noted in Table 2.

The plant community represented in the prairie buffer strips in 2011 contained 118 species including natives and exotics, annuals, perennials, and biennial, comprised of both dicot and monocot plants. Of these plants, 22 contributed an average over 1% relative ground cover in the prairie strips (Table 2), which totaled to 85% of the relative ground cover; 96 other species made up the other 15% relative ground cover. Of the 22 dominant species, seven have been cited for enhancing natural enemy populations, making up 26.8% of the relative ground cover. Of the 96 other species, five species, making up 0.9% the relative ground cover, were recognized by Fiedler and Landis (2007) as attractive to natural enemies of pests in their survey of native plants.

Aphidophagous arthropod community. The soybean aphid predator community was sampled with a sweep-net to test the hypotheses that 1) reconstructed prairie buffer strips harbor more beneficial insects than the adjacent cropland and 2) watersheds with prairie buffer strips have more of beneficial insects than those without. Each sample consisted of 20 sweeps while walking forward with a 30.5 cm diameter canvas sweep net. Each sweep net sample was placed into individual top-closure polyethylene bags, labeled according to its respective date, site, sample number, and stored at -20° C for future identification. In 2009, sampling was conducted monthly from May to September. At each sampling date three randomly located samples were taken in each prairie strip, and at three random locations within the fifth row of the soybeans at the base of each watershed.

In 2011, the insect community was sampled on a monthly basis from June through September, and a weekly basis in July, using a sweep net in the prairie and crop field. Sampling was intensified in July as this corresponded with soybean aphid predation studies. The sampling was conducted weekly to monitor any changes that may have corresponded with changes in soybean aphid predation. In watersheds with multiple prairie or crop strips, one prairie buffer strip was randomly selected and the crop strip above the selected prairie strip was sampled at each sample date. As in 2009, sweep net sampling was conducted using three replications of 20 sweeps within the crop and prairie portion of each watershed in July through September; except for June when only 10 sweeps per vegetation type were made. To account for inconsistencies between June and other sampling dates, June values were multiplied by 2 to represent 20 sweeps and therefore be comparable in magnitude to the other months.

In 2011 insects were also sampled with yellow sticky cards (unbaited Pherocon AM, Trécé, Inc., Adair, OK). This additional sampling tool was added to account for more mobile predators that are not accounted for with a sweep net (Schmidt et al. 2008), during a period when soybean aphids were present within the soybean area. Two yellow sticky card traps were deployed in the soybean area of each experimental unit (watershed) on a weekly basis in July. Two sticky cards were deployed approximately 5 m from each caged soybean plant.

Sticky cards were placed on a wooden stake approximately 1 m above ground. For each sweep net and yellow sticky card sample, aphidophagous insects and arachnids were identified to at least family and to species when possible for members of the Coccinellid and Anthocorid families.

Soybean aphid predation. We tested hypotheses related to the mortality that soybean aphids experienced from natural enemies within each experimental unit (i.e. hypotheses 3-5 listed in the introduction). To test these hypotheses we used methods developed by Gardiner et al. (2009b), in which the population growth of aphids is compared on caged and open plants. To test the third hypothesis that more *A. glycines* will be found on caged soybean plants than soybeans plants without cages due to the presence of natural enemies, pairs of soybean plants were randomly selected throughout each experimental unit and one plant of each pair was covered with a cage. The cage used consisted of a metal tomato cage, covered with white no-see-um mesh fabric (Quest Outfitters, Sarasota, FL) buried in the soil and closed at the top of the cage with wire, so the cage could be opened and closed for data collection. During July 2011, the study site had not experienced an infestation of *A. glycines*; therefore, the plants under study were artificially infested with *A. glycines* from a colony collected in a field in Ames, IA. On 8 July 2011, 10 aphids were introduced to each plant using a probe. Soybean aphid populations were counted once a week following infestation, with the last sampling date on 27 July 2011. Aphids were counted as winged and wingless but combined for analysis. One data point of winged aphids was lost, thus we are underestimating winged aphids on one instance. On the first and second week following infestation, some of the soybean populations were reduced to zero, from the initial 10 aphids, and were re-infested with 10 aphids. The plants paired with the re-infested plants were reduced from their current population back to 10 in order to re-start the experiment. Soybean aphid populations were counted for three weeks following infestation and re-infestation to monitor population changes.

Impact of prairie strips on A. glycines predation in soybean fields (Watershed study). To test the fourth hypothesis that *A. glycines* predation within the watersheds varied by treatment, two pairs of caged and open soybean plants were randomly selected in each experimental unit, totaling 24 pairs (48 total plants) of soybean plants. The location of each cage was determined by first randomly selecting a quarter of each watershed, then a number of paces (both vertically and horizontally) within that section for the exact placement of the cage. Open plants were placed in the same row as the caged plant, approximately one meter away. Soybean plants around the caged and open plants were removed if they made contact.

Impact of proximity to prairie strips on A. glycines predation (Transect study). Of the 12 experimental watersheds included in the overall study, one was selected to test the fifth hypothesis that *A. glycines* predation varied with proximity to prairie. For this experiment we selected a watershed that was isolated from the other watersheds (>500 m), to avoid influence by prairies patches within adjacent watersheds. In the watershed selected (Fig. 2), prairie is located only at the base of the field (i.e. treatment 2). Unlike the previously described experiments in which the watershed is considered the experimental unit, for this study each pair of caged and open soybean plants is considered an experimental unit and the proximity to prairie the treatment. Two sets of five pairs of caged and open plants were established within the watershed; five pairs along the soybean row immediately adjacent to the prairie and five pairs at a row approximately 50 m from the edge of the prairie. The transects were setup approximately perpendicular to the contour of the land. In each transect position; caged and open pairs were approximately 0.5 meters apart. Pairs along the row of soybeans adjacent the prairie were approximately 2 meters apart, and pairs in the row 50 meters into the field were approximately 20 meters apart. At each pair of soybean plants, soybean aphid infestation and monitoring followed the methods outlined previously.

Statistical Analysis. Arthropod abundance is reported as an average of all aphidophagous arthropods, identified to the lowest taxonomic unit possible, of each sweep net sample. Aphid populations are reported as an average of total aphids per plant. In all data collection involving sub-sampling, sub-sample data was collapsed into a mean for the given experimental unit.

To test the first hypothesis, we first used a t-test on the season-long sum of paired data from prairies and soybeans from both 2009 and 2011. To do this, data from crop only treatments was not used. Predator abundance in soybeans was subtracted from predator abundance in prairie buffer strips, then summed for the season long difference combining all seven sampling dates at each plot. On the remaining data a t-test was completed in R. This baseline analysis was completed for total abundance, the most abundant species in each year, exotic ladybird beetles, and native ladybird beetles. After the baseline analyses were completed, a more complex model was built to test in SAS (SAS Institute 2008) for total abundance. To test the first hypothesis we used PROC MIXED in SAS. In PROC MIXED we started with the full model, including all possible covariates: block, plot, treatment, date, vegetation(treatment), block*date, treatment*date, date*vegetation(treatment), testing with a repeated measure of time and a random variable of block*plot*vegetation(treatment). We used the repeated measure algorithm SP(POW) for all analyses due to the assumption that samples from sample dates 1 and 2 are more similar than sample dates 1 and 7. To find the best-fit model, the covariate with the largest P-value was removed from the model, until all covariates were significant at a level $P<0.05$. This analysis was conducted for 2009 and 2011 for total abundance.

For an initial analysis of hypothesis 2, we used a linear ANOVA to compare the season-long total abundance of aphidophagous predators between the soybean fields in all treatments as well as the most abundant species, *Orius insidiosus*, and exotic and native ladybird beetles. We used R to complete the linear ANOVA. After the baseline analyses were completed, a more complex model was built to test in SAS (SAS Institute 2008) for treatment differences. To test the second hypotheses, if abundance in soybean fields differed by treatment, we used PROC MIXED in SAS following the same methods as used in hypothesis 1, using block*plot*treatment as the random variable.

These hypotheses were also analyzed using the Bray-Curtiss distance measure, which calculates the differences in species composition between treatments and vegetation types. Stress levels, or lack of fit between distance matrix and mapping, were too high to compare insect community species differences among watershed treatments or vegetation types using two dimensional graphical analysis, thus communities were compared using Adonis, a permutational multivariate analysis of variance for species composition data (Stevens and Oksanen 2011). The vegan package in R (R Development Core Team 2010) was used to complete the community composition analysis (Oksanen et al. 2011).

The third hypothesis, comparing soybean aphid populations on caged and open soybean plants, was tested using a linear model ANOVA in R (R Development Core Team 2010), including cage treatment in the model. Aphid populations were logarithmic transformed prior to analysis to meet the assumptions of ANOVA and block, treatment and cage were considered fixed effects. To test the fourth and fifth hypotheses, we calculated biological services index (BSI), developed by Gardiner et al. (2009b), to compare caged and open populations scaled to cage populations. It was calculated using the following equation:

$$BSI = (A_c - A_o)/A_c,$$

where A_c is the number of aphids on the caged plant, and A_o is the number of aphids on the open plant. Given this equation, BSI could be negative, suggesting the cage had a negative impact on aphid survival and reproduction. In the case the BSI was calculated as negative, it was considered 0 for the study, which indicates no impact of biological control, as aphids cannot experience negative biological control. Thus, in the analysis, BSI values can range from 0 to 1, increasing with increased predation of soybean aphids. BSI for each pair was calculated using the aphid populations from the last sampling date and were averaged across subsamples within each watershed (i.e. watershed study).

To test the fourth hypothesis, if soybean aphid predation rates differed by treatments applied to watersheds, we conducted an ANOVA with a linear model in R (R Development Core Team 2010) to compare the BSI measured for each treatment applied to watersheds (i.e. the watershed study). Fixed effects tested in the model were block and treatment.

An ANOVA was used to test the fifth hypothesis, if soybean aphid predation rates increase with proximity to prairie edge by comparing BSI measured at two distances from a prairie testing the fixed effect distance from prairie (i.e. transect study).

Results

Aphidophagous arthropod community. In 2009, a total of 5,835 aphidophagous arthropods representing 13 taxa and two groups of unidentified categories were collected with sweep nets. In 2011, a total of 2,013 aphidophagous arthropods representing 21 taxa and two unidentified categories were collected with sweep nets and 231 of 11 taxa were collected with sticky cards, all of which were identified to family or species when possible (Table 3). The categories of taxa collected vary slightly from 2009 to 2011 as methods were slightly different; specifically, spiders were not identified to family or species in 2009 and they were identified when possible in 2011.

In 2009, more predators were collected in the prairie (total: 3933, per 1000: 771.2) than the soybean fields (total: 1902, per 1000: 660.42). Aphid population numbers are reported on a per 1000 sweep basis in addition to the total, as different sampling methodologies were used in 2009 and 2011 and different number of total sweeps, thus per 1000 sweeps gives us a comparable number. The results of the t-tests from season-long totals show prairies have higher total abundance than soybean fields, whereas both exotic and native ladybird beetles are significantly lower in prairie than in soybeans (Table 4). The most abundant species *Orius insidiosus* was not significantly different in abundance in prairie and soybean. The more detailed analysis using PROC MIXED in SAS, which considered individual sample dates instead of the season-long total, resulted in rejecting our first hypothesis, that prairie areas had more abundant predator communities through the whole season. The best fit model for predicting total abundance in 2009 included date (df:1,61; $F=69.32$, $P<0.0001$); date*block ($F=4.68$; df:2, 61; $P=0.0129$), and month*vegetation(treatment) ($F=2.83$; df: 6, 61; $p=0.0171$). After analyzing the interactions, we found that vegetation(treatment), meaning the difference between abundance in prairie and soybean, was significant in June ($F=3.67$; df: 6, 12; $p=0.0263$) and September ($F=5.57$; df: 6, 12; $P=0.0057$).

Looking at the season long total in 2011 more predators were collected in prairie buffer strips (total: 1171, per 1000: 464.8) than soybeans (total: 842; per 1000: 445.1); though on a per 1000 sweep basis, prairie abundance was very similar to soybean abundance. The results of the t-tests from season-long totals show prairies have higher total abundance than soybean fields, whereas neither the number of *Orius insidiosus*, exotic ladybird beetles, nor native ladybird beetles differed significantly between the two vegetation areas (Table 4). More detailed analysis using PROC MIXED in SAS, which considered individual sample dates instead of the season long total, resulted in rejecting our first hypothesis, that predators were more abundant in prairie buffer strips through the whole season. The best fit model for predicting total abundance in 2011 included only date as a significant variable ($F=6.46$; df:1, 125; $P=0.0123$).

Graphical analysis was completed to track the influence of vegetation type and time on ladybird beetle populations, as exotic ladybird species *Harmonia axyridis* is an important predator of the soybean aphid. For 2011, native ladybird beetles are dominant early in the season in the prairie buffer strips, and then begin to decline as populations begin to increase in the soybeans (Figure 4). Ladybird beetle populations were too small to complete a statistically sound analysis with assumptions of normal distributions of residuals.

In an analysis of our second hypothesis, if different prairie treatments impact predator abundance in soybean fields, in 2009 we did not observe an effect of the treatment on the total abundance of predators, nor *Orius insidiosus,* exotic, or native ladybird beetle abundance (Table 5). The same results were observed for 2011 (Table 5). When the full model was analyzed and adjusted to find the best fit model in PROC MIXED, in 2009 only date remained in the model as a significant predictor (F=48.07; df:1, 33; P<0.0001). In 2011, the best fit model included date (F=24.75; df: 1, 69; P<0.0001) and block*date (F=4.81; df: 2, 69; P=0.0111). Upon investigating the block*date interaction we found block was significant in June (F=24.54; df: 2, 9; P<0.05) and Week 1 of July (F=6.66; df: 2, 9; P=0.0168).

The insects collected by sticky cards differed from those collected by a sweep net, as no spiders were collected, and many more syrphid adults were collected. This is expected as sticky cards are measure the activity/density of more mobile arthropods. Among the coccinellids found in the watersheds, the yellow sticky traps captured *Coccinella septempunctata,* which was not collected in soybean fields with a sweep net. The initial linear ANOVA completed in R for total season long abundance concluded that treatment had no effect on abundance (F=1.8134; df: 3, 8; P=0.2227). When completed for syrphids only, the most abundant species, we also found no significant effect of treatment (F=0.8509; df: 3, 8; P=0.5041).

Both hypothesis 1 and 2 were tested using insect abundance data, and though total abundance impacts soybean aphid predation, the insect communities comprising the abundance data also may impact predation rates. Therefore, hypothesis 1 and 2 were also tested using community species composition data instead of abundance data to determine if vegetation type or treatment significantly impacted the makeup of the arthropod predator communities studied. To do this, we used Adonis, which is a multivariate form of ANOVA.

The results of the Adonis test concluded block, vegetation type, and sampling date significantly effected arthropod community composition (Block: F=2.5968, P=0.001, Vegetation: F=13.8710, P=0.001, Date: F=4.9050, P=0.001). Treatment had a minor, though not significant, impact on arthropod community (F=1.4460, P= 0.072). Though the Adonis program does not have the capability of identifying which species comprised the significantly different populations, a graphical analysis shows the changes that occur through the sampling dates and vegetation types (Figure 5).

Soybean aphid predation. The aphid populations on caged and open soybean plants were significantly different (F=33.8470**;** df: 1, 17); P<0.0001). Although we occasionally observed predators within the caged plants (5 out of 72 observations), aphid populations within the caged plants averaged 2,338.7 aphids compared to 208.7 aphids on open plants (Figure 6). These data suggest that the cages prevented aphid mortality from predators. We did not observe an effect of treatment on the number of aphids on each plant, caged or open (F=1.3474; df: 3, 16; P=0.2943), however block had a significant effect on aphid populations (F=12.0893; df: 2, 17; P=0.0005).

Impact of prairie strips on A. glycines predation in soybean fields. The BSI measured across the watersheds indicated that all treatments experienced significant aphid mortality due to predators with BSI values from 0.18 to 0.99. Despite higher abundance of aphid predators in prairies, we did not observe a difference in BSI among any of the watersheds regardless of the presence of prairie (F=0.2889; df: 3,8; P=0.8323, Figure 6). Although the treatments had no observable effect on BSI measured in the watersheds, the treatment that applied the most area in prairie to a watershed (20% on contour) had the highest BSI, and thus greatest amount of aphid biological control; conversely, the lowest BSI was measured in the treatment that had no prairie (i.e. all crop).

Impact of proximity to prairie strips on A. glycines predation. Within the single watershed we measured an average BSI at the edge of the field of 0.76 and 50 m into the field of 0.89 indicative of significant biological control of the soybean aphid in both locations. However, no effect of distance on BSI was detected after three weeks of aphid population growth (F=0.5208; df: 1, 8; P=0.4911).

Discussion

Our first hypothesis compared the abundance of aphidopagous predators between prairie and crop area, and we found that in 2009 and 2011 season-long abundance was higher in prairie areas. In the more complex model analysis, this effect was only significant in June and September of 2009. Despite a more abundant predator community in prairies, we rejected our second hypothesis, that soybean aphid predator abundance and community composition in soybean fields will differ in watersheds with varying proportions of prairie, because no significant difference in abundance or community composition was found among the cropped portions of treatments.

We failed to reject our third hypothesis, as more aphids were found in the exclusion cage plants then the open plants, thus confirming biological control was occurring in the fields and the cages successfully excluded the majority of predators. Despite successful implementation of exclusion cages, we rejected our fourth hypothesis that predation rates would vary among the watersheds with varying amounts of prairie treatments, i.e. no significant differences observed among the watershed treatments. Similarly, we rejected our fifth hypothesis that predation rates will increase with proximity to prairie edge, as predation rates (i.e. BSI) near to the prairie were not significantly different than those further into the soybean field.

We observed very high rates of predation throughout the whole experiment with no impact of prairie quantity or proximity to prairie. Though the experimental design did not capture an impact of prairie strips on insect-derived ecosystem services, we explore factors that may have reduced our power in understanding how prairie influences predator communities and biological control of soybean aphids.

From the Adonis multivariate analysis of community composition, it is clear that the group of species present in prairie was significantly different than the group in soybeans. As greater abundance of predators in prairies and the difference in species composition did not translate into an associated benefit to predator communities or biological control in treatments with prairie, we hypothesize that the natural enemy community in the prairie buffer strips is not impacting insects in surrounding soybean field and associated biological control.

The soybean aphid is an exotic insect pest on an exotic crop native to Asia. One of the primary biological control agents is *Harmonia axyridis*, also native to Asia. Despite the nature of the exotic crop-pest complex, the focus of attracting natural enemies in this project uses native plants and attracts many native arthropod predators. In 2011, exotic ladybird beetles were found only in crop fields in August, and in higher abundance in crop fields than prairie in September. If exotic predators are providing the primary source of biological control of the exotic pest, the added abundance of predators in prairie buffer strips may not be influencing biological control of the soybean aphid inside the field.

The plant species selected and planted to the buffer strips were not selected on the basis of attractiveness to beneficial insects (see Table 2), but instead to represent a diverse mix of native prairie species in Iowa. Very few of these plant species are documented as attractive to aphid predators and therefore it is not unusual that the insect community attracted to prairies may not be the community that is ideal for soybean aphid predation.

Another consideration that may have reduced the power of our experiment was the configuration of the study within a very diverse landscape. Gardiner et al. (2009b) observed within the Midwestern United States that the most accurate model to predict BSI was Simpson's Diversity of the landscape at the level of 1.5 km radius (Gardiner et al. 2009b). The BSI data measured by Gardiner et al. (2009b) study ranges from 0.1 to 1.0, with most BSIs measured above 0.6, similar to our results with BSI means above 0.6 in all treatments. Similarly, Woltz et al. (2012) found that when both landscape diversity and field scale diversity (with buckwheat strips) was varied, changes in biological services were only correlated with landscape diversity, not field scale changes. The landscape of Iowa generally has limited landscape diversity; however, the location of this study was within a National Wildlife Refuge composed of cropland, prairie, and forest (Figure 1). It is not clear what the outcomes of our study would be if conduced in a landscape dominated by row crop production, where the small addition of prairie strips may significantly impact landscape diversity measures at 1.5 km^2 radius level.

Last, the abiotic factors in our study of soybean aphid predation were not controlled, which may have confounded our findings. Within the transect study, we observed that the difference between caged and open aphid populations was significantly higher in the crop field. Populations 50 meters into the crop field averaged 2153 aphids per plant, whereas populations only 1 m into the field averaged 780 aphids per plant. Variation in soybean aphid population growth has been attributed to differences in plant nutrients (Schmidt et al. 2011, Myers and Gratton 2006). Aphids are phloem sap-feeding insects and rely on nutrients from large quantities of sap to support high growth rates (Dixon 1998). To pursue this explanation, we developed a secondary hypothesis to test after the original design was completed. We hypothesized that nitrogen content of the plants in the in-crop transect has higher content then those plants in the by prairie buffer strips.

This hypothesis was tested by sampling soybean plants along the soybean row closest to the prairie and also 50 meters into the field. These samples were dried, ground, and analyzed for total N, C, P, and K in each plant. The plants infested with aphids were not selected, as the goal was to survey the plant population in that area of the field, not the exact plants involved in the transect study, which may have already been affected by aphids. None of the nitrogen results were statistically different but general trends showed plant nitrate levels were higher 50 meters into the crop field ($F=2.7825$; df: 1,18; $P=0.1126$), ammonium levels were higher in proximity to prairie ($F=3.4906$; df: 1, 18; $P=0.07808$), and total plant nitrogen was highest 50 meters into the crop field ($F=3.2099$; df: 1, 18; $P=0.09002$). These results suggest that not only do landscape factors and natural enemy communities have an impact on aphid population dynamics, but bottom up factors, such as nutrient availability also have an impact.

Conclusions. We hypothesized that prairie buffer strips within crop fields would increase abundance of aphidophagous predators and biological control services delivered via soybean aphid predation; however, our data suggest that there was no impact of the amount or placement of prairie buffer strips on either predator abundance in soybean fields nor on biological control. Similarly, we did not observe an impact of proximity to prairie on the biological control of soybean aphid. Despite the higher abundance of predators in prairie strips than in crop fields, the insect community did not appear to have a corresponding impact on the surrounding crop field with variation in prairie quantity and watershed design.

In future studies, more consideration should be given to the design so that both bottom-up and top-down pest regulation accounted for, as well as diversity of the landscape in which the study takes place. Ideally such studies could be represented within a variety of agricultural and natural systems landscapes to see how habitat manipulation responds.

Perennial, non-cropped habitat can be important for conservation of biodiversity within a farm landscape (Van Buskirk and Willi 2004, Schulte et al. 2006) beyond the benefits it can provide in attracting beneficial insects. Although increased biodiversity can improve ecosystem services for growers, during a period of high commodity prices with Conservation Reserve Program rental rates that fail to include future price increases, growers may be less inclined to take land out of production to increase the delivery of ecosystem services (Hellerstein 2010). In order to provide enough incentive to take land out of crop production, benefits need to be clear and of value to farmers so they may consider the risk of changing practices. Ideally, conservation benefits can be maximized while also maximizing profits from crop production in order to make both practices viable. In the current setup of the research design, insect-derived ecosystems services are not being maximized within the landscape as the project is constructed, as no additional pest management services are added by putting prairie into soybean fields. Though other benefits, such as erosion and nutrient run-off reduction have been documented when prairie buffer strips are added to a watershed committed to annual crop production, further investigation is required to ensure that insect-derived ecosystem services can be added to the list of benefits.

Acknowledgements

We thank undergraduate students Meghan Brodersen and Emily Feldcamp for their assistance with field work and dedication to count thousands of aphids and aphid predators; Mike McCarville and Jarad Niemi for help with statistical analyses; Adam Varenhorst for providing aphid colonies for the project; Greg Vannostrand for his patience and assistance with identifying spiders; graduate students in the lab group, Kelly Gill, Rene Hessel, and Bekah Ritson for sharing vehicles and advice on the project; Dennis Lock and other statistics graduate students for assistance with statistical analyses; and faculty, staff, and graduate students working on the STRIPS project at Neal Smith National Wildlife Refuge including Gordon Arbuckle, Jr., Heidi Asbjornsen, Mike Castellano, Nancy Grudens-Shuck, Marry Harris, Matt Helmers, Matt Liebman, Lisa Schulte Moore, John Tyndall, and Chris Witte. Thank you to our partners the U.S. Fish and Wildlife Service and the Neal Smith National Wildlife Refuge, including Pauline Drobney. This work was supported by the National Science Foundation Graduate Research Fellowship. The project at STRIPS is funded by Leopold Center for Sustainable Agriculture, Iowa Department of Agriculture and Land

Stewardship, USDA National Institute for Food and Agriculture, USDA Sustainable Agriculture Research and Education, U.S. Forest Service Northern Research Station, Iowa State University College of Agriculture and Life Sciences, and the National Science Foundation.

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Table 1. Characteristics of experimental watersheds associated with the STRIPS project at Neal Smith National Wildlife Refuge

	Size (ha)	Slope (%)	Treatment (location and percent prairie)	Abbreviation
Block 1 – 1	0.53	7.5	10% at foot slope	foot
Block 1 – 2	0.48	6.6	10% on contour (5% foot slope, 5% up slope)	ten
Block 1 – 3	0.47	6.4	20% on contour (10% foot slope, 10% up slope)	twenty
Block 1 – 4	0.55	8.2	20% on contour (10% foot slope, 10% up slope)	twenty
Block 1 – 5	1.24	8.9	10% on contour (5% foot slope, 5% up slope)	ten
Block 1 – 6	0.84	10.5	100 % soybeans	crop
Block 2 – 1	3.00	7.7	10% on contour (3.3% foot slope, 3.3 side slope, 3.3% up slope)	ten
Block 2 – 2	3.19	6.1	10% at foot slope	foot
Block 2 – 3	0.73	9.3	100 % soybeans	crop
Block 3 – 1	1.18	10.3	10% at foot slope	foot
Block 3 –2	2.4	06.7	20% on contour (6.7% foot slope, 6.7 side slope, 6.7% upslope)	twenty
Block 3 – 3	1.24	6.6	100 % soybeans	crop

Table 2. Plant species found in prairie buffers in 2011 making up greater than 1% relative cover and their importance for attracting insect or spider natural enemies (Adapted from Hirsch 2012)

Common Name	Species name	Plant Type[1]	% Cover	Value for natural enemies
Canadian/Kentucky bluegrass	*Poa compressa/pratensis*	XPM	22.3	None found
Tall goldenrod	*Solidago canadensis*	NPD	10.0	Genus *solidago* attractive (Fiedler and Landis, 2007)
Gray-headed coneflower	*Ratibida pinnata*	NPD	5.8	Attractive, (Fiedler and Landis, 2007)
Queen Anne's lace	*Daucus carota*	XBD	5.5	Extends life of natural enemies (Walton and Isaacs, 2011)
Indian grass	*Sorghastrum nutans*	NPM	4.8	None found
Wild bergamot	*Monarda fistulosa*	NPD	3.8	Genus *menarda* attractive, (Fiedler and Landis, 2007)
Big bluestem	*Andropogon gerardii*	NPM	3.7	None found
Smooth brome	*Bromus inermis*	XPM	3.4	Encyrtidae and Nabidae families more abundant in reseeded brome/alfalfa treatments than three other native and reseeded treatments (O'Neill et al. 2001)
Hairy aster	*Aster pilosus*	NPD	3.1	Genus *aster* attractive, (Fiedler and Landis, 2007)
Reed canary grass	*Phalaris arundinacea*	NPM	2.7	None found
Ox-eye	*Heliopsis helianthoides*	NPD	2.7	None found
Yellow nut grass	*Cyperus esculentus*	NPM	2.4	None found
Foxtail spp.	*Setaria spp.*	XAM	1.9	None found
Little bluestem	*Schizachyrium scoparium*	NPM	1.9	None found
Canada wild rye	*Elymus canadensis*	NPM	1.8	None found
Hedge false bindweed	*Calystegia sepium*	NPD	1.7	None found
Common dandelion	*Taraxacum officinale*	XPD	1.6	None found
Spiderwort	*Tradescantia ohiensis/ bracteata*	NPM	1.4	None found
Side-oats grama	*Bouteloua curtipendula*	NPM	1.3	None found
Poison ivy	*Toxicodendron radicans*	NPD	1.2	None found
Fox sedge	*Carex vulpinoidea*	NPM	1.0	None found
Canada thistle	*Cirsium arvense*	XPD	1.0	*C. septempunctata* abundance higher with high density of *C. arvense* and *E. repens* in barley plots, abundance higher in barley plants exposed to *C. arvense* volatiles (Ninkovic and Pettersson, 2003)

[1] Plant types are represented by X = non-native, N = native, P = perennial, B = biennial, A = annual, D = dicot, M = monocot

Table 3. Total aphidophagous insects and spiders collected in 2009 and 2011 in prairies (mean per 1000 sweep net samples in parentheses)

	2009 Sweep net		**2011 Sweep net**		**2011 Yellow sticky cards**
Taxa	Prairie	Soybean	Prairie	Soybean	Soybean
Unidentified ladybird beetle larvae	0 (0)	6 (2.1)	0 (0)	7 (3.7)	0
Unidentified ladybird beetle adult	1 (0.2)	1 (0.4)	0	0	0
Native Coccinelidae					
Cycloneda munda	23 (4.5)	42 (14.6)	7 (2.8)	8 (4.2)	3
Cycloneda munda larvae	4 (0.8)	5 (1.7)	0 (0)	0 (0)	0
Hippodamia convergens	7 (1.4)	14 (4.9)	6 (2.4)	1 (0.5)	8
Hippodamia convergens larvae	9 (1.8)	7 (2.4)	0 (0)	0 (0)	0
Coleomegilla maculata	1 (0.2)	2 (0.7)	6 (2.4)	10 (5.3)	9
Hippodamia parenthesis	9 (1.8)	1 (0.4)	4 (1.6)	7 (3.7)	2
Coleomegilla maculate larvae	8 (1.6)	7 (2.4)	1 (0.4)	8 (4.2)	0
Adalia bipunctata larvae	NA	NA	0 (0)	1 (0.5)	0
Exotic Coccinelidae					
Harmonia axyridis	229 (44.9)	461 (160.1)	4 (1.6)	12 (6.3)	7
Harmonia axyridis larvae	16 (3.1)	337 (117.0)	1 (0.4)	14 (7.4)	0
Coccinella septempunctata	4 (0.8)	0 (0)	1 (0.4)	0 (0)	10
Coccinella septempunctata larvae	0 (0)	0 (0)	0 (0)	5 (2.6)	0
Other Insects					
Orius insidiosus	960 (188.2)	394 (136.8)	301 (119.4)	408 (215.9)	41
Syrphidae adult	753 (147.7)	44 15.3)	69 (27.4)	60 (31.7)	136
Nabidae	137 (26.9)	189 (65.6)	11 (4.4)	31 (16.4)	0
Dolichopodidae	134 (26.3)	65 (22.6)	0 (0)	0 (0)	2
Chrysopiae Adult	37 (7.25)	19 (6.6)	23 (9.1)	4 (2.1)	11
Hemerobiidae Adult	7 (1.4)	5 (1.7)	1 (0.4)	5 (2.6)	2
Chrysopiae and *Hemerobiidae* larvae	47 (9.2)	NA	84 (29.2)	17 (9.0)	
Spiders					
Unidentified Spiders	1497 (293.5)	189 (65.6)	13 (5.2)	20 (10.6)	0
Thomisidae	NA	NA	400 (158.7)	67 (35.4)	0
Salticidae	NA	NA	105 (41.7)	47 (24.9)	0
Opiliones	57 (11.18)	30 (40.4)	23 (9.1)	8 (4.2)	0
Arenaidae	NA	NA	79 (31.3)	22 (11.6)	0
Tetragnathidae	NA	NA	47 (18.7)	41 (21.7)	0
Oxyopidae	NA	NA	23 (9.1)	11 (5.8)	0
Lycosidae	NA	NA	4 (1.6)	15 (7.9)	0
Linyphiidae	NA	NA	3 (1.2)	8 (4.2)	0
Phiodromidae	NA	NA	3 (1.2)	3 (1.6)	0
Dictynidae	NA	NA	2 (0.8)	2 (1.1)	0
Total	**3933** (771.2)	**1902** (660.42)	**1171** (464.8)	**842** (445.1)	**231**

Table 4. T-test results from 2009 and 2011 comparing prairie and soybean abundance including total abundance, most abundant species *Orius insidiosus*, and exotic and native ladybird beetle populations

Null hypothesis	t-value[1]	P-value	more abundant
2009 total abundance in prairie = soy	3.13	0.014*	prairie
2009 *Orius* abundance in prairie = soy	1.77	0.115	NA
2009 exotic ladybird beetle abundance in prairie = soy	-6.92	0.0001*	soy
2009 native ladybird beetle abundance in prairie = soy	-7.14	<0.0001*	soy
2011 total abundance in prairie = soy	3.82	0.005*	prairie
2011 *Orius* abundance in prairie = soy	0.02	0.986	NA
2011 exotic ladybird beetle abundance in prairie = soy	-1.3703	0.208	NA
2011 native ladybird beetle abundance in prairie = soy	0	1.000	NA

[1] Degrees of freedom for all tests show are 8

* signifies statistical significance rejecting null hypothesis below P = 0.05

Table 5. ANOVA results from testing hypothesis 2, for 2009 and 2011 in total abundance and abundance of most common species or category

Hypothesis	F-value	DF	P-value
2009 total abundance same in all treatments	0.0214	3,44	0.8843
2009 total spider abundance same in all treatments	0.0018	3,44	0.9662
2009 exotic ladybird beetle abundance same in all treatments	0.2489	3,44	0.6203
2009 native ladybird beetle abundance same in all treatments	0.1737	3,44	0.6789
2011 total abundance same in all treatments	0.3281	3,80	0.8050
2011 *Orius* abundance same in all treatments	0.1374	3,80	0.9374
2011 exotic ladybird beetle abundance same in all treatments	1.3411	3,80	0.2669
2011 native ladybird beetle abundance same in all treatments	0.2523	3,80	0.8595

Figure 1. Three experimental blocks in the Neal Smith National Wildlife Refuge fall within a 1.5 km^2 radius circle, within a diverse landscape of crop, reconstructed prairie, and forested area. One of these blocks, Block 2, includes three experimental watersheds (described in detail Table 1). Experimental units are oriented in a small watershed shape, where the arrow indicates water flow direction. Strips of prairie in the watersheds in different quantities and arrangements make up the different treatments applied to watersheds in this study.

Figure 2. A transect study was designed to understand the impact of proximity to prairie strips on biological control of soybean aphids. Experimental watershed Block 3-1 (described in Table 1) was selected for the transect experiment since it is isolated by >500 meters from nearest watershed) from other experimental units. In the transect study, pairs of caged and open plants forma new experimental unit, that are arranged in the first row of soybeans next to the prairie, and approximately 50 m into the field along the contour.

Figure 3. Abundance was analyzed based on sweep net samples from 2011, which were taken once a month in June, August, and September. During July, samples were taken once a week; a monthly average of those is reported here. We did not observe a treatment effect on the abundance of predators within watersheds (F=1.02, P=0.4342). Abundance in prairie and soybeans fields, a habitat treatment nested within watershed treatment, was significantly different (F=4.39, P=0.0418)

Figure 4. A subset of the 2011 sweep net sampled insect community data, exotic and native ladybird beetles displayed seasonal changes in abundance. Total abundance of exotic ladybird beetles starts at zero in both habitats, increases to one in the prairie habitat through July, however in August and September abundance of both exotic and native ladybird beetles remains high in the soybean fields. Seasonal patterns differed between habitat types, as ladybird abundance increased in soybean fields through the season, and abundance declined in the prairie as the season progressed.

Figure 5. An analysis of sweep net insect communities from 2011 using Adonis, a multivariate ANOVA, concluded a significant block, habitat, and date effect on arthropod community composition (Block: F=2.5968, P=0.001, Habitat: F=13.8710, P=0.001, Date: F=4.9050, P=0.001). To visualize the differences by habitat and block, abundance of each predator category is summarized as a percent of the total during each month of the study. These differences are most notable in the shift from the ‘other insects’ category to spiders as the season progresses, and also the presence of exotic ladybird beetles in soybean fields without corresponding abundance in prairie strips. No exotic ladybird beetles were present in June, one exotic ladybird beetle was found in the prairie in July, however in August 19 exotic ladybird beetles were found in the soybean field while none were present in the prairie samples.

Figure 6. In 2011, aphid density on artificially infested individual soybean plants, an average of 6 caged and 6 open plants for each treatment. Each watershed had 2 pairs of caged and open plants, for a total of 48 plants in the study. There was a significant difference

in aphid density between caged and open plants ($F=38.073$, $P<0.001$), showing that cages were successful at excluding biological control agents. Treatment did not affect the aphid populations ($F=2.148$, $P=0.1318$, however block also had a significant effect ($F=12.338$, $P<0.0001$)

Figure 7. In 2011, the biocontrol services index (BSI) among watershed treatments were above 0.5 and indicative of significant aphid predation. There was no difference in BSI among any of the watershed treatments after three weeks of observation ($F=0.3227$, $P=0.8093$). BSI was measured as the difference in aphid populations between open and caged plants divided by the caged population (described in detail in Methods: Statistical Analysis).

Figure 1.

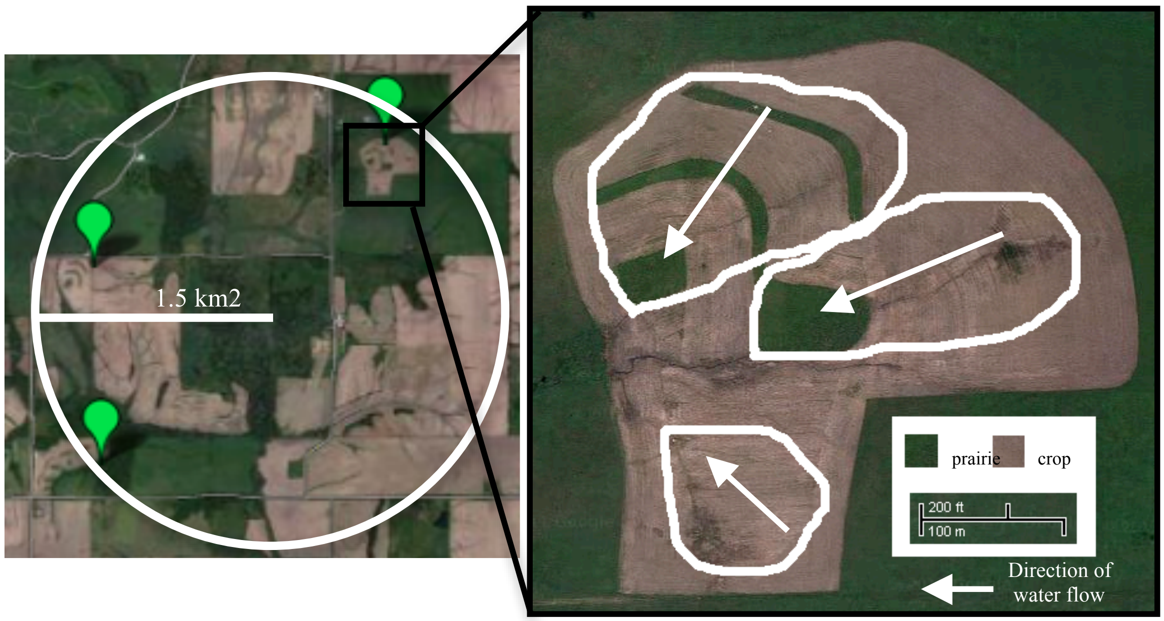


Figure 2.

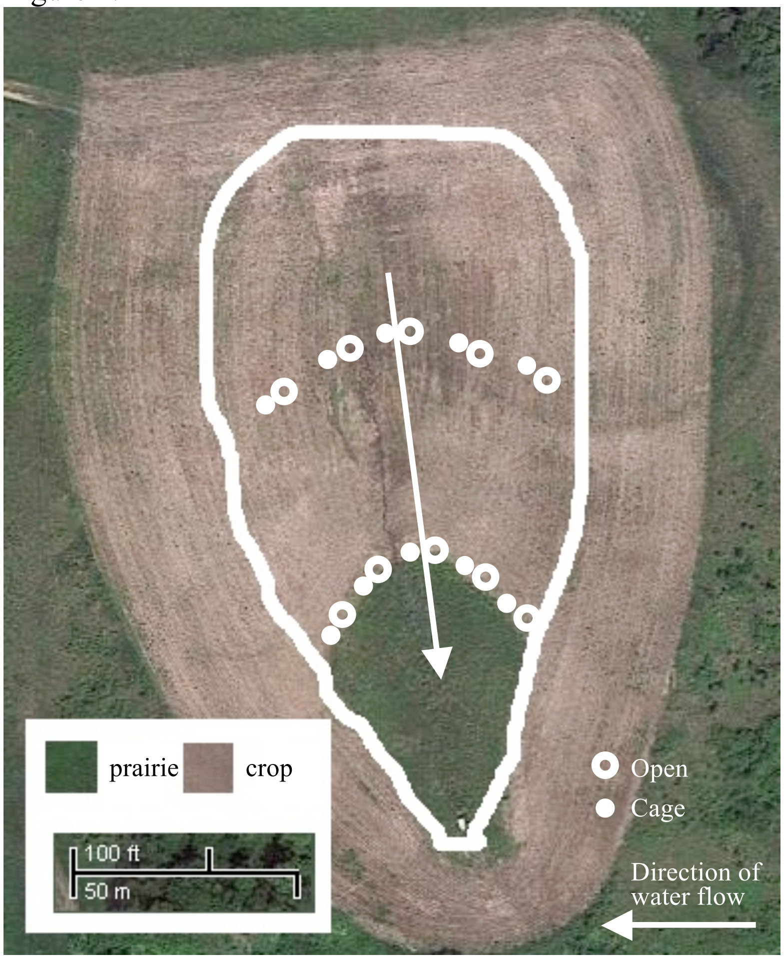


Figure 3.

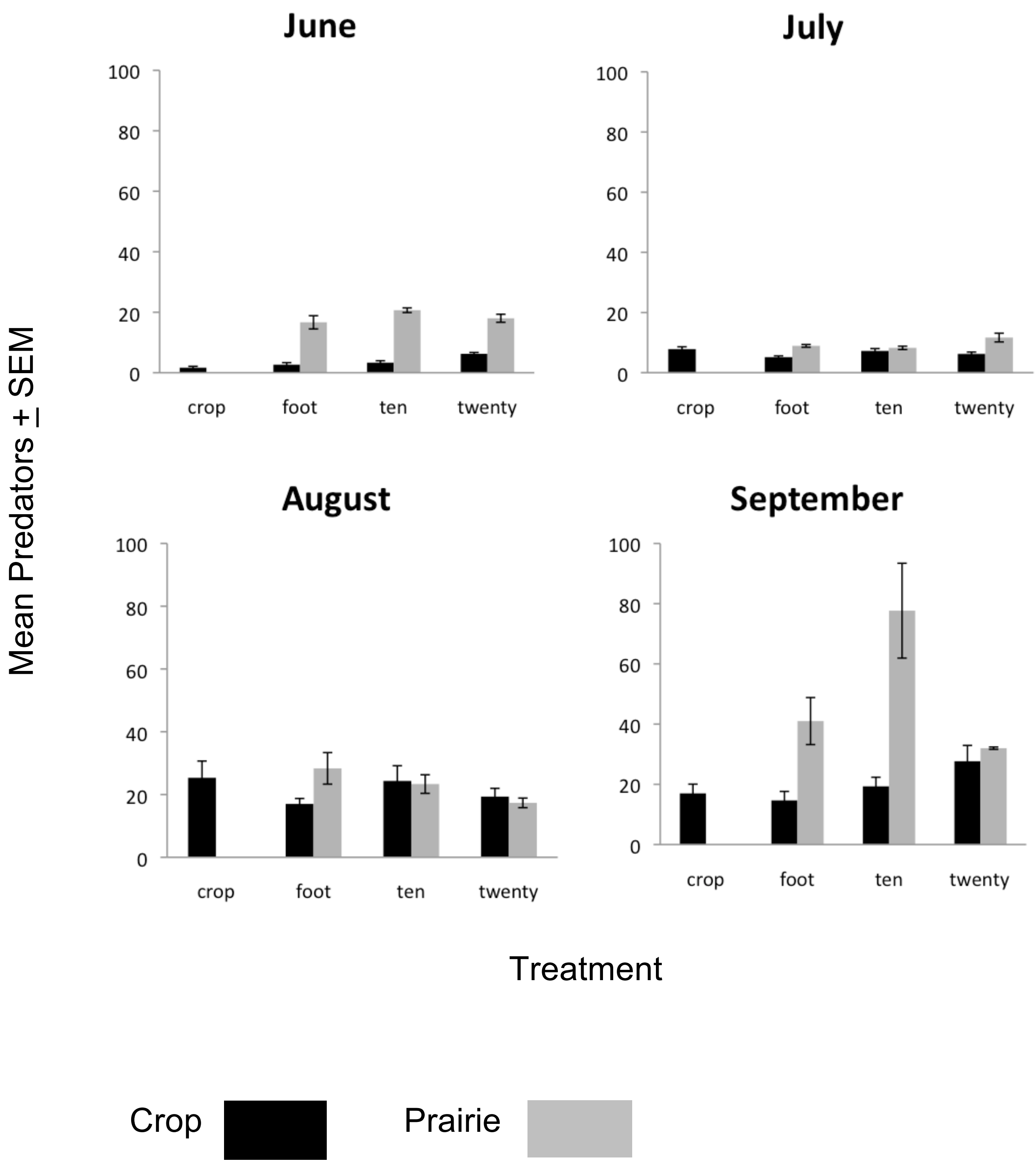
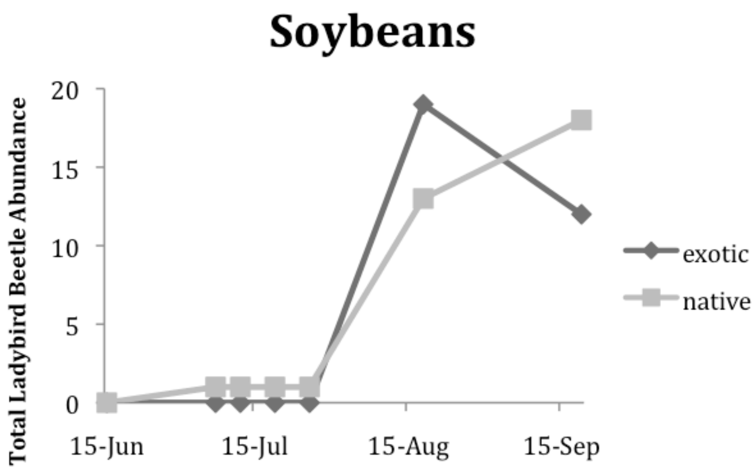

June
July
August
September
100
80
60
40
20
0
crop
foot
ten
twenty
Mean Predators + SEM
Treatment
Crop
Prairie

Figure 4.


Soybeans
Total Ladybird Beetle Abundance
20
15
10
5
0
15-Jun
15-Jul
15-Aug
15-Sep
exotic
native

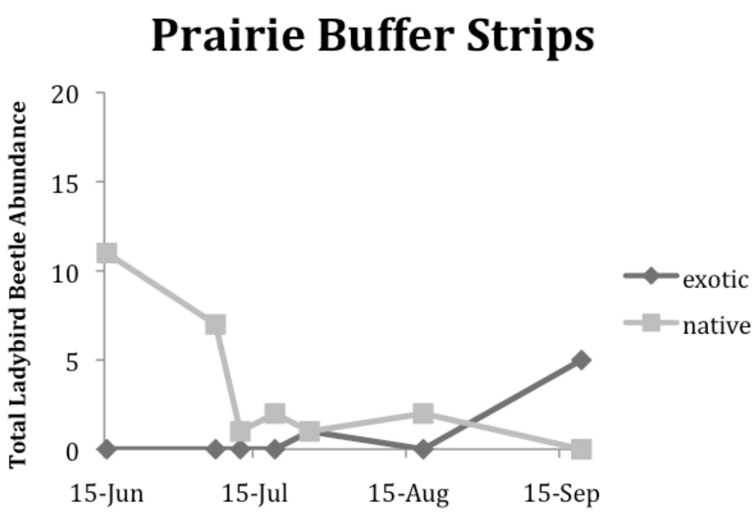

Prairie Buffer Strips
Total Ladybird Beetle Abundance
20
15
10
5
0
15-Jun
15-Jul
15-Aug
15-Sep
exotic
native

Figure 5.

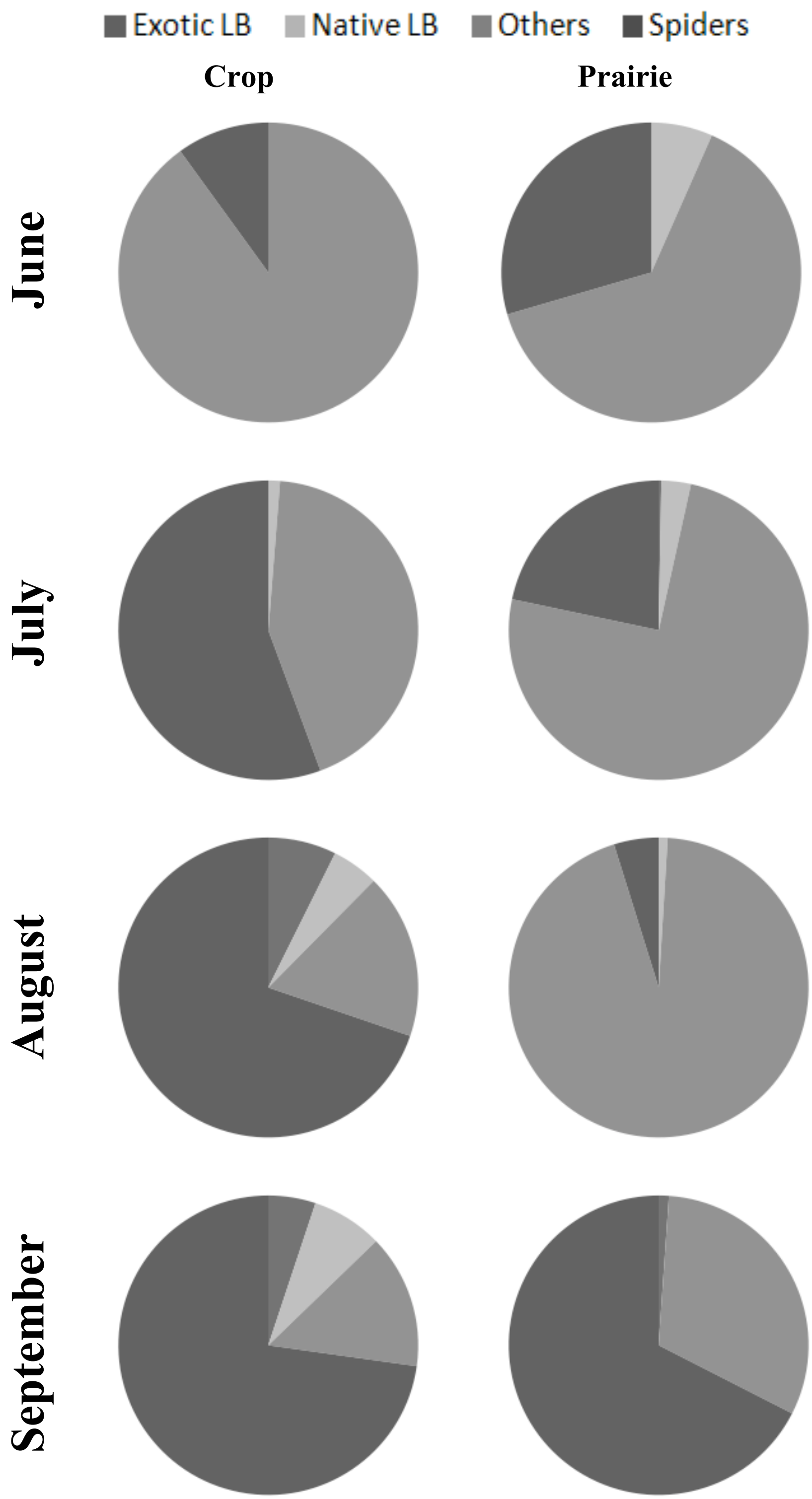

Exotic LB
Native LB
Others
Spiders
Crop
Prairie
June
July
August
September

Figure 6.

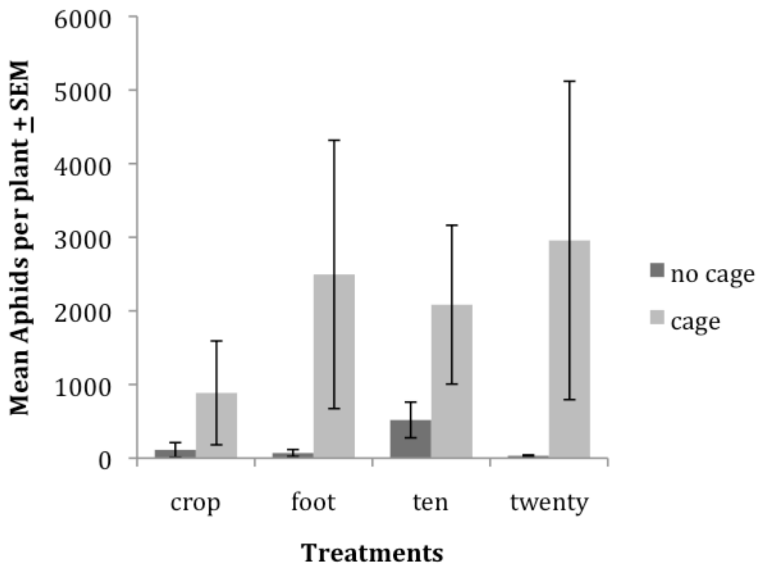
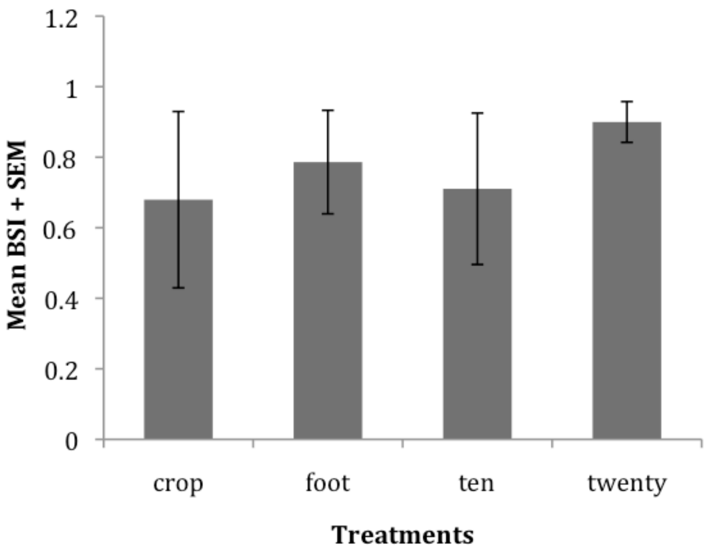

6000
5000
4000
3000
2000
1000
0
Mean Aphids per plant ± SEM
crop
foot
ten
twenty
Treatments
no cage
cage

Figure 7.



Chapter 3. Grazing cattle on reconstructed prairie to balance conservation needs and production goals: a case study in central Iowa, USA

A manuscript to be submitted to the

Journal of Renewable Agriculture and Food Systems

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Abstract

Grazing cattle on reconstructed prairies is a solution proposed by land managers and graziers in Iowa, as an opportunity to balance the conservation goals of incorporating perennial, native plants into the Iowa landscape while maintaining the productivity and profitability of the state's agricultural lands. Though grazing native plants is common to much of the Western United States, the limited amount of grazing lands in Iowa are dominated by exotic, cool-season grasses and legumes. In a case study at Whiterock Conservancy in Coon Rapids, Iowa we explored the nutritional quality and yields of reconstructed native plant grassland and prairie through clip sampling. Results from sampling found that all of the nutritional requirements of cattle would not be met with the harvested samples, although some aspects of nutrition may be achieved during the season. We created an economic budget model based on this case study, which suggests that grazing prairie is most profitable for graziers when a reduced rental rate is offered by land owners to provide a service of disturbance to the prairie. A review of the ecological literature suggests that grazing has the potential to maintain or increase plant biodiversity, though native plant abundance was not well studied. This review also concluded that water quality and wildlife populations could be maintained under strategic grazing management. Communication should be a priority in designing management strategies for conservation lands that involve multiple stakeholders.

Key Words: ecosystem services, Whiterock Conservancy, forage quality, multifunctional

Introduction

Prairie is often used in the Iowa landscape for conservation purposes – whether to improve water quality[1], increase carbon sequestration[2], or to create habitat for upland game birds[3]. These conservation purposes are often defined as ecosystem services, goods or services of value to human society that are derived from ecosystem processes or ecosystem stocks, or "the benefits that people obtain from ecosystems"[4].

Various governmental programs (i.e. Conservation Reserve Program [CRP]) and private organizations (i.e. Pheasants Forever) encourage planting prairie through cost-share or annual payment based programs, in order to maintain or enhance specific or general ecosystem services. Under current agricultural economic circumstances, these payments are often not enough to keep landowners or managers invested in perennial grass cover and more conservation spending and targeted practices may be required to maintain conservation of sensitive lands[5]. As crop and land prices remain high, perennial grass conservation acres may be taken out of conservation and put into row crop production[5]. In an era of increasing need to preserve and enhance ecosystem services due to a changing climate and continued environmental degradation, it is essential to find alternative systems that seek balance between conservation needs and production needs for economic viability of farm operations.

One option that is pioneering the balancing act of conservation and production is the concept of grazing livestock on reconstructed ecosystems that were established for conservation efforts. Grazing livestock in conservation areas may allow land managers to generate profit from the land while maintaining or enhancing the conservation benefits of native perennial plants.

Grazing systems in Iowa are characterized by non-native, low-diversity, cool season grass and legume pastures, therefore very little research has been conducted on grazing native plants or prairies in Iowa. A large volume of literature on grazing prairie exists in the range sciences, however, the landscape, context, and environment of range sciences grazing systems is much different than those of Iowa. This case study is not intended to suggest replacing cool-season grass systems with prairie systems, but instead to incorporate prairie into the agricultural landscape of Iowa and to use the prairie as an addition to current grazing systems.

Though the majority of the landscape of Iowa is in row crop production, grasslands with native plant species exist in areas unsuitable for tillage, such as river-valleys and marginal farmland seeded to grasses for soil conservation. In order to create the greatest benefit from these grasslands, human management is needed to maintain and improve the quality and function of these areas. Exclusion of grazing animals from prairie has been the typical management strategy for conservation, despite the fact that large grazing animals have been present on the tallgrass prairie landscape for thousands of years[6]. Bison (*Bos bison*), a large herbivore, has been identified as a keystone species in the tallgrass prairie[7], however now in many prairie reconstructions, large herbivores are absent and their role as a keystone species is missing. Prescribed fire and mowing are typical disturbance regimes in Iowa for prairie management; now, grazing by domestic livestock is being considered as an alternative disturbance regime[8]. Though cattle have somewhat different grazing behaviors than bison, they can play similar roles conservation efforts combining grazing and fire[9].

In a recent survey of graziers in Wisconsin, researchers found that thirty-five percent of respondents were interested in using native grass as pasture[10]. However, in this study, producers indicated unfamiliarity with the identification and establishment of native grasses, suggesting more resources are needed to share with producers who are interested in incorporating prairie into their grazing operation.

Plant communities are dynamic through the season and through time, and in order to design grazing management strategies, the forage availability and quality must be understood throughout the season, and among different plant functional groups. Forages change in quality and quantity throughout the season but this change has not been documented for reconstructed prairies or grasslands in Iowa. This lack of information makes it difficult to optimize animal production, which requires high yields and high quality forage. Without this information, graziers who choose to graze reconstructed grasslands take-on additional economic and animal performance risk. In a study in Wisconsin, Doll et al. found that over 50% of forage quality variability was attributed to factors that farmers could not control[11].

Ecological considerations

Though using reconstructed prairie areas to graze cattle may be beneficial to agricultural production, the ecological impacts are more variable. One objection by prairie land managers to grazing prairies is that the diverse native plant community will suffer due to grazing. A study in Alberta, Canada, compared grazed prairies with areas excluding cattle for the last 70 years and found grazing had no effect on species richness or evenness on either soil type tested ($P > 0.1$)[12]. Shannon's diversity index was not different between grazed and no-graze areas.

A study in Iowa compared areas that were (1) grazed with cattle, (2) burned, or (3) burned and grazed. Shannon's diversity index was not significantly impacted by management treatments, however the grazing treatment had equal species richness as the burn-only areas, both higher than the burn + graze treatment ($P < 0.01$)[13].

Another study in Iowa, at the Neal Smith National Wildlife Refuge compared grazed and ungrazed reconstructed prairie areas. Bison and elk (*Cervus elaphus*) were included in the study area to provide the grazing treatment. The study found no significant difference in Simpson's diversity index between the grazed and ungrazed treatment[14].

Four studies at the Konza Prairie Biological Station in Kansas compared various combinations of grazing animals (bison or cattle), burning, burning and grazing, and mowing. Towne et al. conducted a study that compared cattle grazing, bison grazing, and no-graze treatments[15]. Species richness at a small (plot) and large (pasture) spatial scale increased in response to grazing by both cattle and bison ($P < 0.0001$), whereas no-graze treatment areas did not increase in richness over time. Shannon's Diversity indices at both scales also increased over time in response to cattle and bison grazing and did not increase in no-graze plots ($P < 0.0001$). For both richness and diversity, increases were larger for bison grazed areas than those grazed by cattle.

Another study that took place at the Konza Prairie related the effects of bison grazing, fire and topography to plant diversity[16]. All significant differences reported are at $P < 0.05$.

The study considers the effect of bison after four years of grazing. Species richness was higher with grazing than the no-graze treatment at the lowland, but not upland, under an annual burning regime. When burned every 4 years, the grazed treatment had higher richness for both the lowland and the upland. Species evenness was higher in grazed treatments in the uplands under annual and quadrennial burning, whereas the grazed treatment had lower evenness when annually burned in the lowland. Shannon's diversity index was higher in the grazed treatment in the uplands on annual and quadrennial burned areas, but only in the lowlands on annual burned areas.

In another study comparing fire and grazing interactions at Konza Prairie, Spasojevic et al. investigated the changes in plant diversity over 22 years with and without grazing since 1987 (19 years of grazing) on annual, quadrennial, and 20-year burn cycles[17]. Though there is not a control (with no grazing or fire treatment) in this experiment, burning is currently the mainstream management tool of prairies, so can be considered a reference point for comparison with grazing as a management tool. Species richness and Simpson's diversity index were higher in grazed and burned areas than only burned areas ($P < 0.0001$). In this study, researchers recognized that areas burned or grazed diverged in plant community composition over time.

Collins et al. studied mowing and grazing in two separate experiments at the Konza Prairie in Kansas[18]. The mowing study found no significant difference between total plant richness (total number of species found) in the control treatment (un-manipulated, no burn or fire), the fire-only treatment, and the mow + fire treatments. In the grazing portion of the study, the graze-only and burn + graze treatments were statistically equal, and significantly higher than the control, and the burn-only treatment ($P < 0.0001$).

Hickmann et al. studied the impact of various stocking densities and grazing systems on plant diversity at the Kansas State University Range Research Unit in the Flint Hills of Kansas[19]. Shannon's Diversity Index (P-value not reported) and species richness ($P < 0.001$) were higher in grazed than no-graze areas. There were no differences between grazing systems (continuous vs. rest rotation) in terms of richness and diversity. However, stocking density had a significant effect on richness and diversity ($P < 0.05$). Richness in high-density stocking was higher than low and moderate density and diversity in high-density stocking was higher than low-density.

Grazing reconstructed prairies may impact not only diversity, but also native plant abundance. Relative native plant abundance is measured as the quantity of plant materials that are native as a proportion of the total plant material measured, which can be measured in a variety of ways including by ground cover, percent biomass, or line point transects.

A study in Iowa took place at a large tract of prairie managed by The Nature Conservancy, the Broken Kettle Grassland[13]. The percent cover of native species was significantly lower in both the grazed and burned + grazed treatment as compared to the burned-only treatment. The percent cover by cool-season grasses and exotic forbs increased in grazed and burned + grazed treatments relative to the burn-only treatment. An analysis of the species composition in this study showed that each treatment corresponded with a different set of common and uncommon species, which suggests that the results are more complicated than examining only diversity indices or native plant abundance.

A study in Wisconsin investigated bison grazing in a management intensive rotational grazing scheme, which consisted of grazing the bison herd for about 2 days in each paddock (4 paddock replications) in July, August, and on either a monoculture or low-diversity mix of native warm-season grasses[20]. Over the course of 8 years of measurement, the native grass plant cover was reduced from about 80% to about 20%, however this was not compared to a control of a non-grazed treatment and no P-values were reported on the trend.

A study in eastern Iowa compared grazing, mowing, and a no management control, showed no difference in treatments, was done on a former cool season pasture, starting only a month after seeding to prairie species[21]. Over the course of the three years after seeding, no significant difference in native plant abundance was shown between control, grazed, and mowed treatments, however the overall abundance of natives relative to total abundance was low, less than 15%.

Perennial plants, for example prairie, are often planted in order to slow water movement, increase water infiltration, and decrease erosion. Grazing animals offer physical changes to an ecosystem that may improve water quality services as compared to non-grazed ecosystems. According to Hubbard et al., some of these benefits include additions of organic matter in manure resulting in increased water holding capacity, increased infiltration rates, improved soil structure, and growth in beneficial soil microbial and mesofauna populations[22]. Despite potential positive contributions to water quality, livestock on the landscape negatively affect water quality when the number of livestock exceeds the carrying capacity of a field or watershed, resulting in water quality problems related to sediment, nutrients, and pathogens[22].

Poor management of pastures has been well documented for contributing to poor water quality[23]. Pasture management practices to consider when grazing prairies include avoidance of over-grazing, stockpiling of manure in one area due to shade or water access, and high animal densities over extended periods of time.

A study in North Dakota investigated runoff and erosion of differently managed pastures and rangelands using rainfall simulation, including treatments that were burned, grazed, and included native and non-native plants[24]. From this study, percent bare ground was the most important factor for explaining loss of soil and vegetative dry matter was the most important for explaining runoff, however, soil properties and root weight generally were not important in explaining soil loss and runoff[24]. The conclusions of the research conducted by Hofmann and Ries suggests that if grazing or harvesting prairies could be done in a way that minimizes bare ground, nutrient and sediment run-off prevention could be maintained.

Changes in the water cycle will occur when disturbance, such as a grazing event, takes place. Evapotranspiration is a key process to reduce the movement of water through leaching or runoff, both of which cause nutrient and sediment pollution and flooding. An important aspect of adding perennial plants to the landscape is the ability of perennial plants to quickly take water out of the cycle where it is readily available for transport to stream channels or leachable to ground water. Increased evapotranspiration rates will allow the water cycle to accelerate in order to reduce water run-off and leaching.

A study in Kansas compared evapotranspiration rates of a grazed and un-grazed prairie throughout the season. The season long difference between grazed and un-grazed treatments was a 6.1% reduction in evapotranspiration in the grazed prairie, however immediately after grazing plant evaporation was up to 40% lower than the un-grazed treatment[25]. The overall small difference was due to more actively growing and transpiring young leaves after grazing and a delay in senescence by plants that were grazed[25]. This research indicates that though initial decreases in evapotranspiration may cause decreased efficiency of prairie areas to maintain water quality, the season-long impact will be small.

The research surveyed on the grazing animal's impact on water quality provides examples that when managed to avoid common problems of overgrazing and dense animal populations, water quality benefits of adding prairie to the landscape can be maintained even under grazing animal disturbance.

Wildlife is another concern regarding adding grazing to reconstructed native grassland ecosystems in Iowa. Nesting of grassland birds typically takes place during June and July, a time period when producers may look to use warm season grasses when cool season pastures are less productive, however since the goals of the Whiterock Conservancy stakeholders are centered on sustainable land management, not solely economic profitability, grazing during grassland bird nesting season is not possible. This concern will be addressed through delayed grazing events, after nesting birds have minimal risk to grazing. Ecologists at Whiterock Conservancy will survey grassland areas to ensure minimal risk before transporting cattle to graze at a given prairie location.

A study in North Dakota on Waterfowl Production Areas found that stocking density did not have a significant effect on upland sandpiper (*Bartramia longicauda*) nest success, but the time of grazing did. Spring grazing treatments reduced nest success as compared to fall-only grazing and no grazing treatments[26].

In a study on breeding bird abundance at the Konza Prairie in Kansas, researchers found upland sandpipers and grasshopper sparrows (*Ammodramus savannarum*) responded positively to grazed treatments, whereas Henslow's sparrow (*Ammodramus henslowii)* responded negatively to grazing (significance at $P < 0.05$)[27]. Henslow's sparrow responded positively to no-graze treatments one to three years after burning, but in the year of burning and after four plus years since burning, populations negatively responded to no-graze treatment most likely due to their need for litter and dead vegetation left standing ($P=0.007$)[27]. Dickcissels (*Spiza Americana*) responded positively to no-graze treatments in the year of burning and first year after burning, but in two plus years since burning, populations negatively responded to no-graze treatment ($P=0.013$) [27].

The impact of grazing on upland game birds varies because different game species have different habitat requirements. Bobwhite quail (*Colinus virginianus*) were reported in higher numbers in high-intensity, low frequency grazing systems and continuously grazing systems compared to no-graze systems[28]. The authors hypothesize the increased abundance is due to bare ground, tall forbs, and less grass in grazed compared to undisturbed systems[28].

Whiterock Conservancy history and goals

Whiterock Conservancy is a land trust that was created in 2004, when the Garst Family started a gradual land gifting to the newly formed nonprofit conservation organization[29]. Eventually, Whiterock Conservancy will be a 5,366-acre (2172 ha) conservancy, but currently the organization owns and manages over 2,500 ac (1012 ha). The mission of Whiterock Conservancy is to foster "a resilient and self-renewing Iowa landscape by integrating economics, social and ecological land management strategies and engaging the public via outdoor recreation and education"[29].

At the outset of the discussion the goals of Whiterock Conservancy relative to grazing cattle (*Bos taurus*) in reconstructed native ecosystems were focused on defining grazing as a management tool for a broad audience. These goals include connecting stakeholders to discuss grazing as a management tool, produce consensus recommendations and language of grazing as a management tool, publish recommendations to a broad audience in Iowa, and expose primary issues in implementation of grazing as a management tool.

Though these overarching goals are guided by a desire to make grazing a management tool that is accessible and useful to an audience across Iowa and beyond, Whiterock Conservancy also plans to implement this management strategy on their land. Through the work involved in achieving their goals, Whiterock Conservancy is able to research questions for their own management plan while creating a body of knowledge that may be useful to a broad audience.

Portions of Whiterock Conservancy's land base are dedicated to reconstructed native ecosystems and some land remains in cool-season pasture and row crop production. The long-term goal is to manage the reconstructed ecosystems as a part of a working agricultural landscape, where agricultural lands are not separated in management from conservation lands. To accomplish this goal, Whiterock Conservancy plans to graze cattle on the reconstructed lands. Whiterock Conservancy identified three areas to begin grazing (Figure

1), but first approached Iowa State University to develop forage quality and livestock nutrition calendars, so they could graze in a way that balanced the benefit to the land, the cattle, and to the economic profitability of the grazing operation.

Before Whiterock Conservancy initiates a grazing management plan for reconstructed native ecosystems, agronomic, animal nutrition, and economic information was needed to maximize the success of the project. This case study documents the process of data collection, analysis, and discussion that took place at Whiterock Conservancy in order to design a site-specific plan that meets the many goals of the stakeholders.

Methodology

The first step in the design process was to survey the agronomic potential of the land on a biomass yield and forage quality basis. After agronomic information was assessed, it was compared with animal nutrition data and livestock scenarios. Agronomic, livestock nutrition, ecological and economic data was shared with stakeholders in the Whiterock Conservancy project to develop a management plan.

Agronomic data collection

Weather data was used from a weather station at Guthrie Center, approximately 24 kilometers from Whiterock Conservancy. Monthly mean temperatures and monthly total precipitation was calculated from the Iowa Environmental Mesonet at the closest available weather station[30].

Two areas at Whiterock Conservancy were identified as target areas for research on grazing. The first area, the warm season grassland (WSG) site (30.9 ac, 12.5 ha) is located on Marshall soils, which are loess derived and well-drained, formed under tallgrass prairie, but converted to row-cropland during the last two centuries[31]. This area was planted to a low-diversity warm-season grass mixture in 2002, including species *Andropogon gerardii, Panicum virgatum, and Sorghastrum nutans.* This area was mowed on a monthly basis to ~45 cm height for the first three growing seasons to reduce competition by annual weeds, and has since been managed with prescribed fire during the time period 20 April – 7 May in 2008 and 2009. This area is currently under a Conservation Reserve Program contract and sample areas were "bought back".

The second area, the reconstructed prairie (RP) plot (43.5 ac, 17.6 ha) is also located on Marshall soils. In 2004, this area was planted to high diversity warm-season grassland species: *Andropogon gerardii, Schizachyrium scoparium, Sorghastrum nutans, Bouteloua curtipendula, Elymus virginiana, Baptisia lactea, Eryngium yuccifolium, Astragalus canadensis, Artemisia ludiviciana, Lespedeza capitata, Zizia aurea, Asclepias tuberosa, Rudbeckia hirta, Heliopsis helianthoides, Silphium lacianatum, Ratibida pinnata, Chamaecrista fasciculata, Solidago rigida, Tradescantia ohiensis, Amorpha canescens, Echinacea pallida, Dalea purpurea, Monarda fistulosa, Liatris pycnostachya, Symphyotrichum novaeangliae*. The area was mowed to 45 cm for the first three years to reduce competition by annual weeds, and has since been managed with prescribed fire during the time period April 20-May 7 in the years 2008 and 2009 (burned twice due to lack of burn coverage during the first burn).

In 2010, forage nutrition and total available forage was sampled at the two ecosystem reconstruction areas with 1.08 ft^2 (0.1 m^2) quadrats located every 16.4 ft (5 m) along a 82.0 ft (25 m) transect (five quadrats per transect). Samples from each transect were combined for analysis. One transect was laid for every three hectares within each grassland type, i.e. eight transects at both the RP and WSG. Transect locations at the RP and WSG were determined by randomly selecting GPS coordinates in the area.

In the WSG and RP at each transect, forage was sampled on a bi-monthly basis for available forage located 5.9 inches (15 cm) above the soil surface. Each sample represented cumulative forage growth for the season, with no re-growth sampling. Samples were dried and weighed prior to forage analysis in order to determine the available forage on a dry matter basis. Once per month, prior to drying, samples were sorted into plant functional group: warm-season grass, cool-season grass, forb, legume, sedge, and non-herbaceous material.

In 2011, in lieu of transects, four samples were collected at each sampling date in the WSG and RP. Each sample consisted of four 1.08 ft^2 (0.1 m^2) quadrats. The sample locations were selected using randomized GPS coordinates, different with each sampling date, and different from the area sample in 2010. Once per month samples were sorted into functional groups, this time sorting into warm season grass, cool season grass, forb, and other (sedges, woody material, and legumes), as the ‘other’ categories did not provide sufficient biomass in 2010 to complete forage quality lab analyses. All other methods were followed as in 2010.

The following forage quality parameters were measured in the lab: neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), crude protein (CP), ash, and dry matter content (DM). Fiber procedures, including NDF, ADF, and ADL were conducted following the methods of Vogel et al.[32] with a modification of 4 ml of heat stable α-amylase to the NDF solution before extraction. The Iowa State University Soil and Plant Analysis Lab in the Agronomy Department completed nitrogen and carbon analysis by automated combustion[33].

Forage quality data was converted into relevant animal nutrition components in order to compare the forage quality available with the animal nutrition needs using the following equations:

1) Crude Protein (CP) = 6.25 * Nitrogen[34]
2) Dry Matter Intake (DMI) = 120 / % NDF[35]
3) Total Digestible Nutrients (TDN) = A – B x % ADF, for mixed prairie and forbs A=102.56, B=1.069; for warm season grassland, cool season grasses, and warm season grasses A = 102.33, B=1.14[36]

Animal nutrition scenarios

Animal nutrition calendars for crude protein and total digestible nutrients are based on a nutritional calendar developed at Iowa State University based on the National Research Council Nutrient Requirements of Beef Cattle[37]. In this nutritional calendar, we assume a cow calf pair with calving in March. The nutritional calendar for dry matter intake is based on an adaption from the National Research Council Nutrient Requirements of Beef

Cattle[38,39]. Dry matter intake values are also reported for a beef cow, assuming calving in March.

Economic budgets

Many approaches to include grazing prairie in a grazing system in Iowa are possible. The three scenarios presented in this paper were developed based on discussions with the research team and on the limited examples of producers grazing animals on native plants in Iowa. From these discussions, we determined that the most likely scenarios do not include season-long grazing of prairies, but instead targeted grazing when cool season pastures are in the summer slump but warm season grasses are highly productive. The three scenarios included are 1) a typical practice in Iowa of purchasing hay during the summer slump, 2) grazing private CRP land for four weeks in late July or early August; 3) grazing public land for four weeks in late July or early August and paying a typical rental rate (not discounted for lower quality prairie forage); and 4) grazing public land for four weeks in late July or early August and paying a reduced rental rate (discounted for lower quality prairie forage).

The economic models are based on an expected 2.0 ton/ac (734.3 kg/ha) available forage for late July or early August grazing, above the 5.9 in. (15 cm) clipping height. Typical rangeland management recommends harvesting 50% of forage with grazing. As the yield does not include the biomass below 5.9 inches (15 cm), we approximated 1.4 tons/ac (503.0 kg/ha) targeted for biomass harvest by grazing or haying.

With this harvest objective, approximately 4 cow/calf pairs can be stocked per acre (0.4 ha) of land, with an estimated daily intake of 24.3 pounds (11.0 kg) dry matter for an estimated 28 days on pasture. We assume a herd of 100 cows, thus 25 ac (10.1 ha) of land is needed. This is a high stocking rate compared to typical stocking rates on cool season grass pastures in Iowa, however, the livestock will only remain on the land for a small amount of the grazing season, thus avoiding overgrazing. Total forage requirements for duration of the 100 cow/calf pair system is 34.0 ton (30,800.0 kg, 67,902.4 lb).

Hay costs were based on Whiterock Conservancy sale prices in 2011[40]. Hay is typically sold on a quality basis, and the prices used in the economic budgets represent low quality hay, of which CRP hay would be considered. Land rental rates are the average income from pasture rental at Whiterock Conservancy in 2011[40]. CRP government payment rates were averaged from CRP contracts at Whiterock Conservancy between older contracts with lower rates and new contracts with higher rates. Grazing CRP land is not a typical management strategy; Farm Service Agency (FSA) regulations allow disturbance to occur only once per three years or one third of land every year. However, in many years an emergency haying and grazing exception is made by the FSA. In an emergency use declaration year, if a producer chooses to graze or hay CRP land, the producer is required to pay in return 25% of the original payment[41]. Fencing rates are based on the Iowa State Ag Decision Maker Budgets[42], assuming the 25 acres being fenced is a square area, and the fencing cost is spread over 10 years. All economic data considered can be viewed in Table 1.

Results

Agronomic and livestock considerations

Mean monthly temperatures varied very little between 2010 and 2011 and showed the same general trend through the growing season (Figure 2). Precipitation in 2010 was higher than in 2011 through much of the growing season, especially in June, July, and August, the months of most biomass production of prairies.

In 2010, live forage yields at the reconstructed prairie (RP) peaked near 2.75 ton per acre, increasing through the early fall before peaking (Figure 3). Warm season grasses contributed the majority of dry matter biomass, followed by forbs and cool season grasses. At the RP, crude protein, dry matter intake, and total digestible nutrients decreased throughout the growing season in a linear fashion (Figure 4). Crude protein and dry matter intake of the forage samples at the reconstructed prairie did not meet the nutritional needs of beef cows for most of the season (Figure 4a, b). However, total digestible nutrients exceeded the needs of the cows throughout the season (Figure 4c).

Because the RP consisted of a diverse mix of warm season grasses, forbs, and cool season grasses, an analysis was completed of functional group components. In all three measures of forage quality, forbs had the highest nutrient value (Figure 5). Despite higher quality, crude protein demands were not met by forbs during the growing season (Figure 5a), however forbs exceeded dry matter intake and total digestible nutrient requirements throughout the season (Figure 5b,c). Warm season and cool season grasses had similar quality levels for all three indicators, and only exceeded nutritional needs for total digestible nutrients but were otherwise below nutritional requirements.

The warm season grassland followed similar yield patters as the RP in 2010, with increasing live biomass yields increasing through late August into early September, peaking at an average of 2.67 tons per acre (Figure 6). After May warm season grass made up greater than 88% of the dry biomass yields.

In 2010 similar quality results were found at WSG, with decreasing forage quality parameters as the season progresses (Figure 7). Crude protein and dry matter intake of the forage samples from the warm season grassland did not meet the nutritional needs of beef cows during the growing season (Figure 7a, b). However, total digestible nutrients exceeded the needs of the cows throughout the season (Figure 7c). An analysis of components was not completed due to the dominance of warm season grass.

In 2011, live forage yields at RP peaked at 2.44 tons per acre, increasing through the August and peaking earlier than 2010 (Figure 8). Though warm season grasses contributed the highest amount to dry biomass yields, forbs contributed a higher percentage in 2011, up to 36% as compared to up to 24% in 2010. As in 2010 at RP, crude protein, dry matter intake, and total digestible nutrients decreased throughout the growing season in a linear fashion (Figure 9). Crude protein did not meet the nutritional needs of beef cows for most of the season (Figure 9a). Dry matter intake was slightly higher through the season, remaining above the nutritional requirements through midseason (Figure 9b). Similar to 2010, total digestible nutrients in 2011 exceeded the needs of the cows throughout the season (Figure 9c).

An analysis of components was completed again in 2011, and the results were similar to 2010. In all three measures of forage quality, forbs had the highest nutrient value and warm season and cool season grasses had similar values for all indicators (Figure 10).

In 2011, WSG yields were lower than both 2010 yields and 2011 RP yields, peaking in August at 1.98 tons per acre (Figure 11). Also, warm season grasses continued to dominate the biomass yields with an even higher proportion at over 96%. WSG forage quality parameters followed the same patterns as 2010 (Figure 12).

Economic considerations

During the summer slump in Iowa, the summer months when cool-season pastures are unproductive and warm-season pastures are most productive, graziers typically have three options: overgraze cool season pastures, purchase hay, or find warm-season pastures to graze. Though overgrazing may be low-cost in the short term, the long-term ecological effects of soil erosion and invasion of weeds may not be worth the short-term benefit.

The next option, if not to overgraze, is to purchase hay. Of the three scenarios considered and compared (Table 2), purchasing hay was the most expensive. Of the three options, grazing public lands had the lowest cost.

The lowest cost option is to graze cattle on rented public lands. In this scenario, graziers are not expected to invest in the infrastructure of planting prairies or building fences, which reduces the risk to the farm operation. Public land managers are accustomed to investing in disturbance regimes, such as fire, so investing in grazing infrastructure is not an unreasonable possibility. Although graziers do pay a rental rate to graze cattle on public land, this cost is lower than the investment cost in infrastructure.

The middle cost option is to graze CRP lands during emergency use years. This requires the farm to invest in fencing, watering systems, and reduction in CRP payment, however the costs are still less than purchasing hay. This option may not be available in all years, as not all years are declared haying emergencies. As trends show more weather extremes in the future[43], more emergency use years may be declared, thus making this scenario a more common option.

Discussion

Balancing agronomics, economics, and ecosystem services

The results of our study suggest that very early in the growing season crude protein and total digestible nutrient needs of beef cows will be met, however from June onward only total digestible nutrients in the prairie forage are sufficient to meet the needs of the livestock. At no point in the season is the dry matter intake requirement of the cattle met. Despite the results which suggest that prairie forage is not meeting nutritional needs of the cattle, a handful of producers in Iowa and many producers throughout the South and Western United States have a forage base dominated by warm season grasses and prairie species and are able to maintain profitable enterprises with cattle maintaining proper body conditioning scores[44] (Chapter 4).

Though the nutrient requirements are not met based on our results, other interpretations may exist to create a functioning system. The samples analyzed in this study, which were clipped from prairies, may not represent the actual nutritional intake of the animal as animals may select for higher quality forage in a diverse stand[45,46]. Clipped samples represent all plant material, not necessarily what an animal will selectively graze and consume, which is dependent on what grazing system is used for livestock that may increase or decrease selectivity. Research from Tennessee found that tall fescue (*Festuca arundinacea*) and Korean lespedeza (*Lespedeza stipulacea*) based forage selected by animals was higher in crude protein, lower in acid detergent fiber, and was more digestible then available forage[45]. In Australia, Moir found grasses selected by cattle had 50% higher protein content compared to that of total pasture available[46].

In addition, when comparing prairie forage with the typical cool-season grass pasture forages used in Iowa, a typical Iowa pasture will exceed the protein needs of cattle throughout the growing season, but total digestible nutrient levels are under the cattle needs through the whole season[37]. Though cool season pastures meet some of the nutritional needs of cattle season-long, they tend to drop in production during the summer slump of high temperatures in July and August and may produce very little forage biomass.

If cattle are showing signs of lower body conditioning scores, prairie forages could be supplemented with higher protein and more digestible feed sources to create a diet that meets the animal's nutritional requirements. Further economic research would need to be done in order to understand the costs and benefits of supplementing prairie forage grazing systems.

From the economic scenarios examined, the best economic option is to pay a reduced rental fee for grazing public prairie lands, while leaving the responsibility of grazing infrastructure with the host organization. Even if paying a full rental rate, the costs are comparable to investing in infrastructure in order to graze private CRP land. In order to minimize risk, allowing the governmental or conservation organization to maintain infrastructure may be an ideal option.

In a recent study of Iowa graziers using prairie as forage, one grazier identified fencing and water as the biggest barrier to implementation on the grazier's own land, but when conservation organizations invest in the infrastructure, it's a great deal for the grazier. Bruce Carney, a farmer from central Iowa who has been grazing public prairie lands for the last two years, in personal communication said "I think the biggest obstacle …to making this work … is infrastructure. You got to figure out fence and you have to figure out water. Cattle like to have both of them. If you're talking to a public or federal agency … it's got to have a legal fence around it or they're not going to let you on it" (January 2012).

However, as the discussion of grazing CRP broadens and policies may change to embrace the ecosystem benefits of grazing CRP lands, it may be more economically viable for a grazier to graze their own CRP or prairie, particularly, if cost-share programs existed to help producers invest in water and fencing systems. Under current CRP policies this is not a reality, though non-CRP land enrolled in programs such as Environmental Quality Incentives Program (EQIP) may be more flexible to support creative solutions to profitability and ecosystem services.

Of the eight papers surveyed on grazing and plant diversity, five concluded that the addition of a grazing treatment to either a no management treatment or a burn only treatment increased plant diversity. Three studies reported no significant differences in diversity between management types. None of the studies reported a decline in diversity after a grazing treatment was applied. Of the three papers on native plant abundance, two concluded that there was a decrease in relative native plant abundance after grazing treatments were applied and one paper resulted in no significant differences of relative native plant abundance between grazed, mowed, and control treatments.

Though the results of the literature review suggest that grazing prairie may improve or at least maintain biodiversity, more studies are needed to investigate native plant abundance and native plant diversity in the same study, as the studies only investigating abundance suggested a decline in native plants. In any grazing prairie scenario it is advised to monitor changes in plant populations to avoid an unintended decrease in biodiversity related ecosystem services.

The results of the water quality literature review conclude that grazing conservation areas does not necessarily negatively affect water quality, but in fact can improve water purification services, or at least maintain current services. The most important management guideline to maintain water quality services is to avoid overgrazing and graze in a way that maintains ground cover.

To best maintain wildlife populations, the literature review suggests that a good management practice is to leave some areas ungrazed as refuge for wildlife that require more dense cover than the grazed areas. A similar concept of burning and grazing in different areas, often known as patch burn grazing, will allow a more diverse group of species to benefit from the landscape[47]. In addition, work from Wisconsin emphasizes the risk of implementing the same management strategy at the same time each year. Grazing during the same season on an annual basis caused pressure to negatively influence the same functional group year after year[20]. This research project also suggested that grazing early in a prairie reconstruction might cause the negative result of low native plant cover as the plant community is new and more susceptible to pressure.

Conclusion – moving forward

Each prairie in Iowa and across the United States is different when considering the interaction between plant community, management goals, history, and local environment. Thus, to design and implement a management strategy that includes grazing should not look identical to the results from this case study.

Based on the information in this case study, Whiterock Conservancy has designed a management strategy to begin grazing in a way that balances agronomic, animal nutrition, economic, and ecological considerations. In August of 2012, cattle will be grazed on a reconstructed prairie for 2-4 weeks. This time was selected to avoid grazing during grassland bird nesting season, which ends in July or August. Though this is not the time of the season with the highest quality forage, a large quantity of biomass is available in order to help maintain body conditioning score while meeting the ecological goals of Whiterock Conservancy. To address potential nutrient deficiencies, cattle will be monitored and if body conditioning scores begin to fall due to insufficient nutrition, grains or higher quality hay will be used to supplement prairie forage.

Though grazing prairies is not likely to become a highly profitable venture in Iowa due to lower quality forage, this case study suggests that it is possible to maintain economic viability while maintaining or improving ecosystem services. This case study presents the opportunity for both conservation land management to benefit and graziers to benefit. Conservation lands may benefit from increased diversity and new, diversified disturbance regimes. Graziers may benefit from saving money from decreased hay purchases, expanding their land base for grazing, and providing time for home pastures to rest while grazing prairie lands.

Graziers and conservation land managers may have different approaches to grazing prairies, as graziers may be more focused on cattle body conditioning scores or weight gain while conservation land managers may be more focused on diversity and wildlife habitat. If grazing is implemented as a land management strategy, it will be critical to have strong and up front communication between conservation managers and graziers to avoid overgrazing of prairies and compromising conservation or negative influences on cattle health.

Acknowledgements

We thank undergraduate students Andrew Stammer, Guan Lai, Katy Darrah, and Rosie Olander for their assistance with field work, data entry, and lab work; staff at Whiterock Conservancy for support and assistance with equipment and field work; my lab mate Stefans Gailans for help with field work and support through the research process; and Patricia Patrick for all the hours she spent helping with the forage lab analyses. This work was supported by the National Science Foundation Graduate Research Fellowship, the Leopold Center for Sustainable Agriculture, and the Grass-Based Livestock Working Group.

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Table 1: Financial data for grazing scenario economic budgets.

	Costs/year	Notes	Reference
Fencing ($/25 acres)	$517.60	Assumption: for a 25 acre square area, the perimeter fencing required is 4,174 feet. Non-electric high tensile fence is $1.24 per foot, for a total of $5,176. We assume fencing will last approximately 10 years, making yearly fencing costs $517.60	42
Land Rental Rates ($/acre)	$53	$53 was average pasture rental rate at Whiterock Conservancy, average in Guthrie County, 2011	40
Grazing public land fee ($/acre)	$35	Public land managers may provide land free of costs, or may charge a fee or rental rate. Likely to charge a small fee, not whole rental rate. Assumption: fee of $35/acre	Communication with Loren Lown, January 2012
Purchased Hay ($/ton)	$45	High quality hay in 2011 sold at $78/ton, whereas low quality hay and CRP hay sold at $45/ton. To represent similar hay quality as grazing scenarios, the low quality hay cost is used in the budget.	40
CRP Payment ($/acre)	$132.5	Average between older and newer contract rates at Whiterock Conservancy. Older contracts are about $110/acre, new contracts about $155/acre.	40
CRP Emergency Penalty ($/acre)	$33.13	CRP lands can be grazed or hayed when emergency use programs are declared. Cost of grazing or haying can be up to 25%. We assume 25% of $132.50 will be paid as a penalty, $33.13/acre	41

Table 2. Economic budget for grazing scenarios in Iowa. Each scenario assumes 100 cow calf pairs are grazing or eating hay for 4 weeks.

	Scenario 1: Feeding hay	Scenario 2: grazing CRP	Scenario 3: grazing Public land, full rental rate	Scenario 4: grazing Public land, reduced rental rate
Purchased Hay	$1,527.75	---	---	---
Fencing Costs	---	$517.60	---	---
CRP penalty (25%)	---	$828.13	---	---
Land Rental	---	---	$1,325.00	$875.00
Total Costs	**$1,527.75**	**$1,345.85**	**$1,325.00**	**$875.00**

Figure 1. Whiterock Conservancy is located outside of Coon Rapids, Iowa, USA (Map sources: Google Maps and Iowa Department of Natural Resources. The two areas outlined below, the reconstructed prairie and warm season grassland, are the focus of a study on forage production and forage quality, to better design and implement grazing management on conservation lands.

Figure 2: Mean annual temperatures at Guthrie Center, a weather station approximately 24 kilometers from Whiterock Conservancy, follow similar trends and do not differ greatly between 2010 and 2011. Precipitation is higher throughout the season in 2010 than in 2011.

Figure 3: Live forage yields from 2010 at the reconstructed prairie increased through early September peaking above 2.5 tons per acre, and decrease sharply in late September. The majority of live biomass is comprised of warm season grasses, followed by forbs as the second largest biomass category.

Figure 4: Forage quality is represented by percent crude protein (a), dry matter intake as a percentage of body weight (b), and total digestible nutrients as a percent of biomass (c). In 2010 at the reconstructed prairie, crude protein and dry matter intake of composite samples were below animal nutrition requirements for most of the season, whereas total digestible nutrients exceeded requirements.

Figure 5: In 2010 at the reconstructed prairie, the forb functional group provided the highest nutritional content for crude protein (a), dry matter intake (b), and total digestible nutrients (c). Warm season and cool season grasses had comparable nutrient levels in all forage quality categories.

Figure 6: Live forage yields from 2010 at the warm season grassland increased through August peaking above 2.5 tons per acre, and decreased in September. Warm season grasses dominated the live biomass yields with very little contribution by forbs, cool season grasses, and other plant types.

Figure 7: Forage quality values from 2010 at the warm season grassland show crude protein (a) and dry matter intake (b) were below animal nutrition requirements throughout the growing season, whereas total digestible nutrients (c) exceeded requirements.

Figure 8: Live forage yields from 2011 at the reconstructed prairie increased through early August peaking above 2 tons per acre, followed by a gradual decrease through late August, September, and October.

Figure 9: In 2011 at the reconstructed prairie, crude protein (a) and dry matter intake (b) levels started above animal requirements early in the season and then fell below nutritional needs later in the season. Total digestible nutrients exceeded nutritional requirements throughout the growing season.

Figure 10: As in 2010, sorted samples from 2011 showed that forbs provided the highest forage quality at the reconstructed prairie for crude protein (a), dry matter intake (b), and total digestible nutrients (c). Forbs exceeded nutrient requirements of throughout the season for dry matter intake and part of the season for crude protein. Forbs, warm season grasses, and cool season grasses all exceeded nutritional requirements for total digestible nutrients.

Figure 11: Live forage yields from 2011 at the warm season grassland increased through August peaking above 1.5 tons per acre. Warm season grasses made up the majority of live biomass.

Figure 12: Forage from the warm season grassland in 2011 did not meet the needs of crude protein (a) or dry matter intake (b), however exceeded the needs of total digestible nutrients (c).

Figure 1.

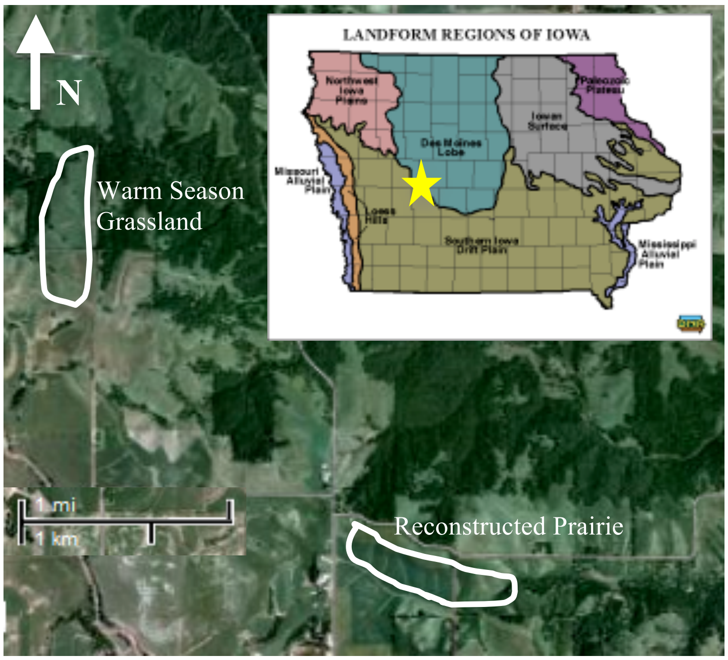
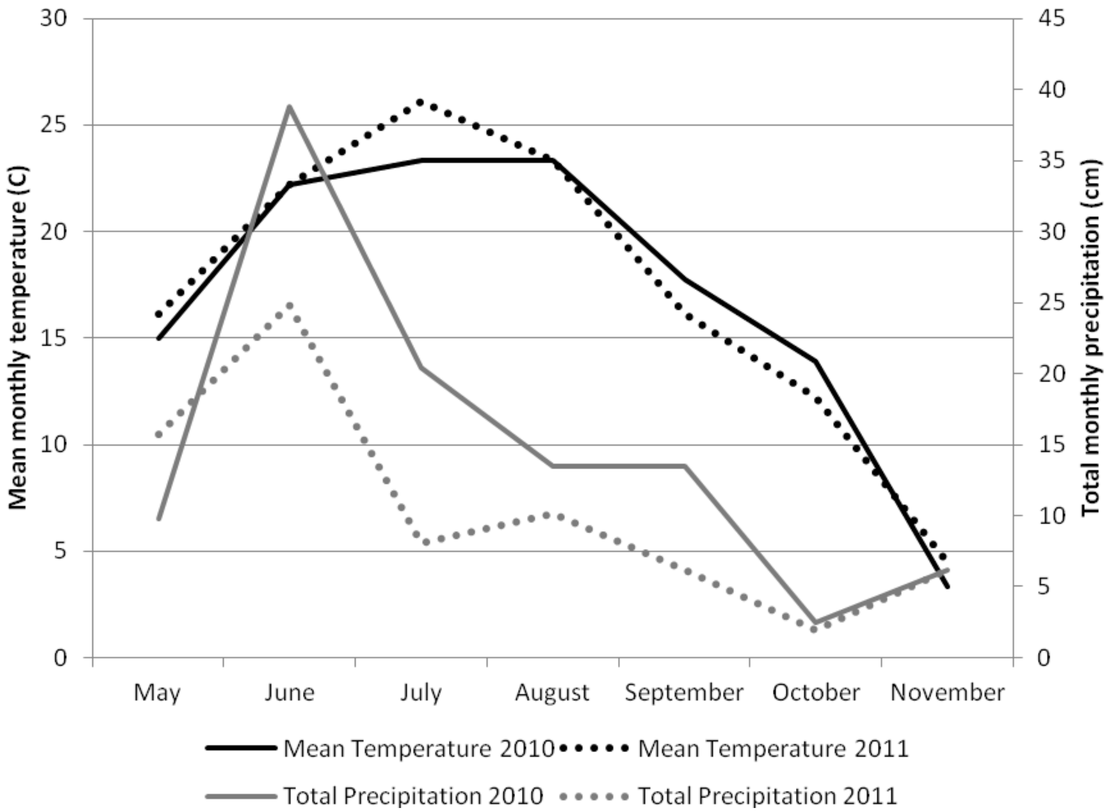

LANDFORM REGIONS OF IOWA
Northwest Iowa Plains
Des Moines Lobe
Iowan Surface
Paleozoic Plateau
Missouri Alluvial Plain
Loess Hills
Southern Iowa Drift Plain
Mississippi Alluvial Plain
N
Warm Season Grassland
1 mi
1 km
Reconstructed Prairie

Figure 2:



30
25
20
15
10
5
0
45
40
35
30
25
20
15
10
5
0
Mean monthly temperature (C)
Total monthly precipitation (cm)
May
June
July
August
September
October
November
Mean Temperature 2010
Mean Temperature 2011
Total Precipitation 2010
Total Precipitation 2011

Figure 3.

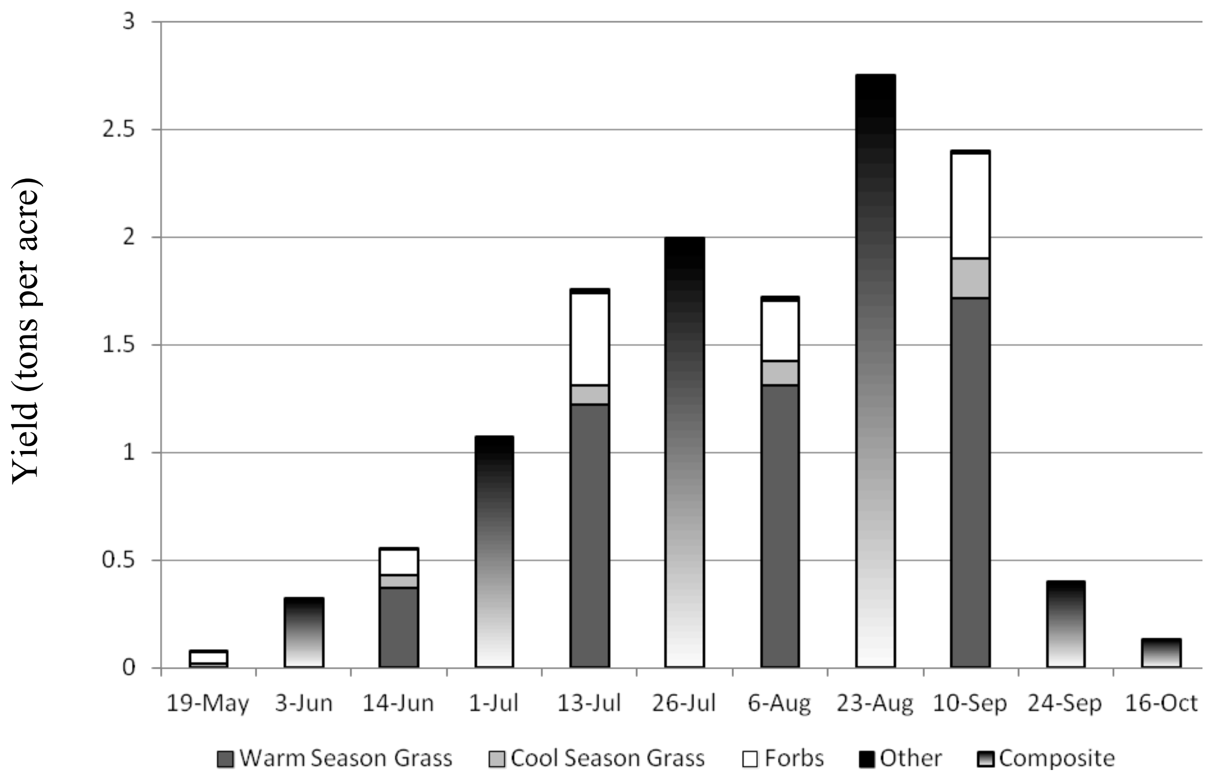

Yield (tons per acre)
3
2.5
2
1.5
1
0.5
0
19-May
3-Jun
14-Jun
1-Jul
13-Jul
26-Jul
6-Aug
23-Aug
10-Sep
24-Sep
16-Oct
Warm Season Grass
Cool Season Grass
Forbs
Other
Composite

Figure 4:

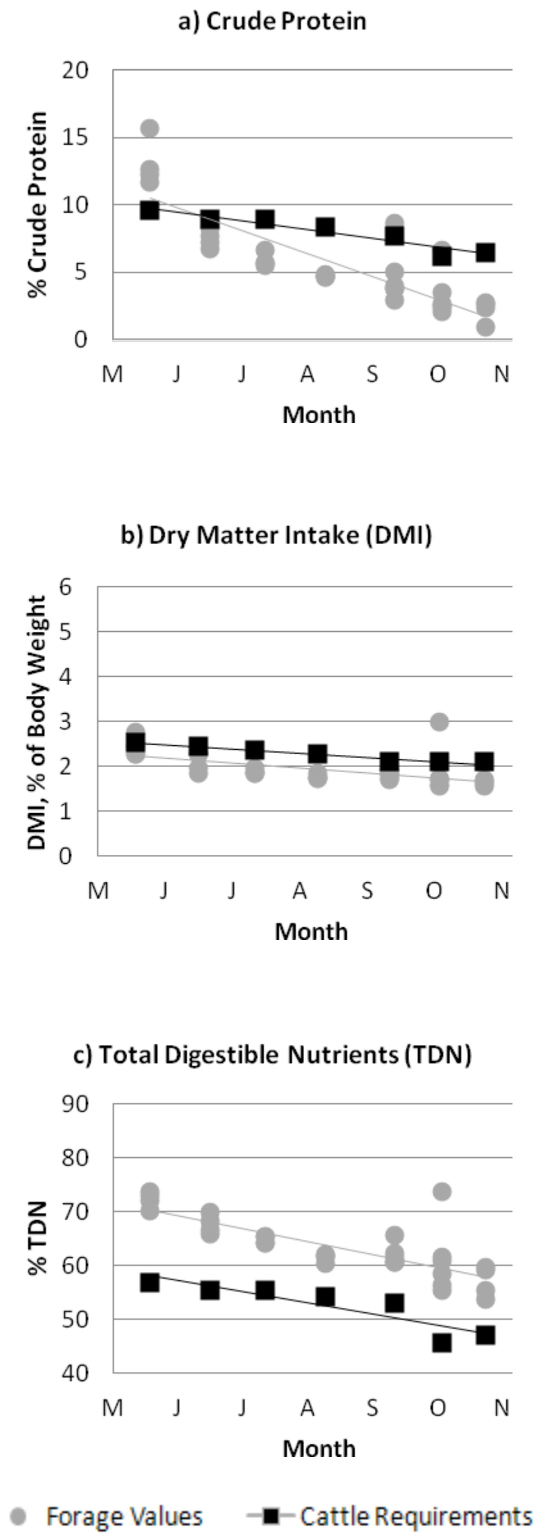

a) Crude Protein
% Crude Protein
20
15
10
5
0
M
J
J
A
S
O
N
Month
b) Dry Matter Intake (DMI)
DMI, % of Body Weight
6
5
4
3
2
1
0
M
J
J
A
S
O
N
Month
c) Total Digestible Nutrients (TDN)
% TDN
90
80
70
60
50
40
M
J
J
A
S
O
N
Month
Forage Values
Cattle Requirements

Figure 5:

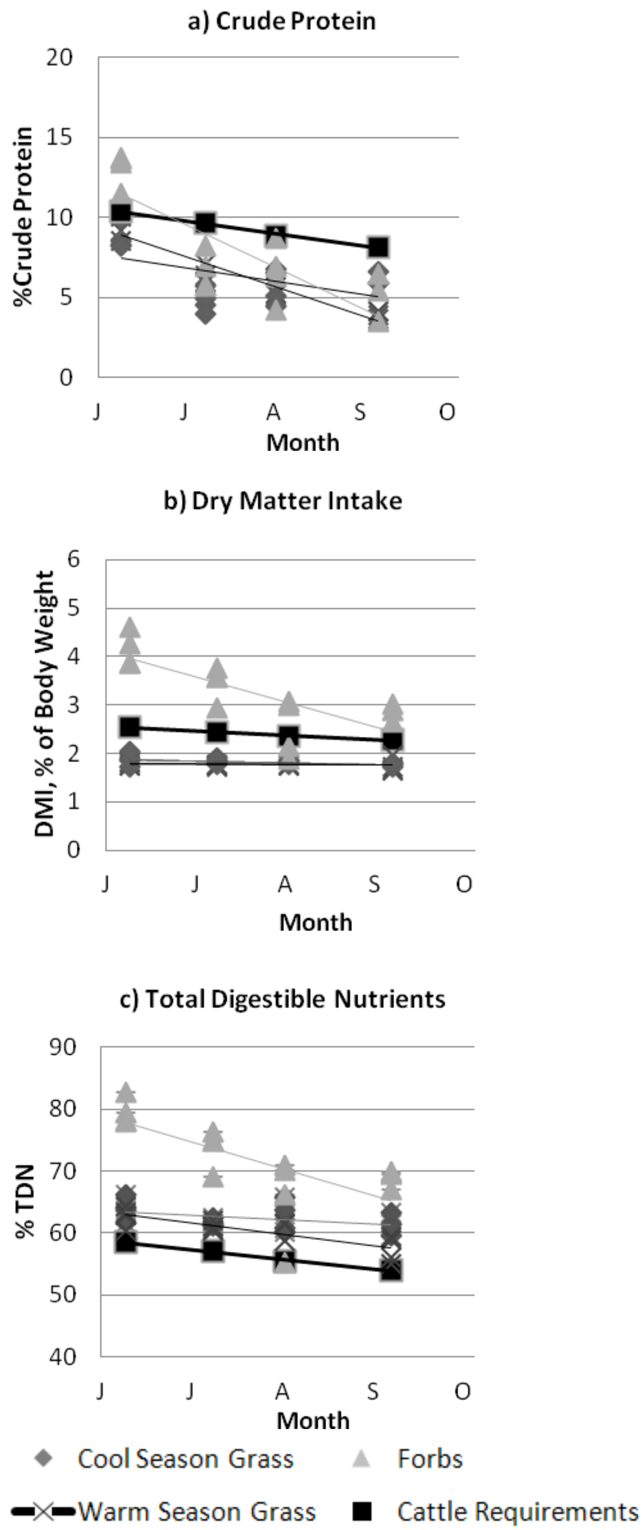

a) Crude Protein
%Crude Protein
20
15
10
5
0
J J A S O
Month
b) Dry Matter Intake
DMI, % of Body Weight
6
5
4
3
2
1
0
J J A S O
Month
c) Total Digestible Nutrients
% TDN
90
80
70
60
50
40
J J A S O
Month
Cool Season Grass
Forbs
Warm Season Grass
Cattle Requirements

Figure 6:

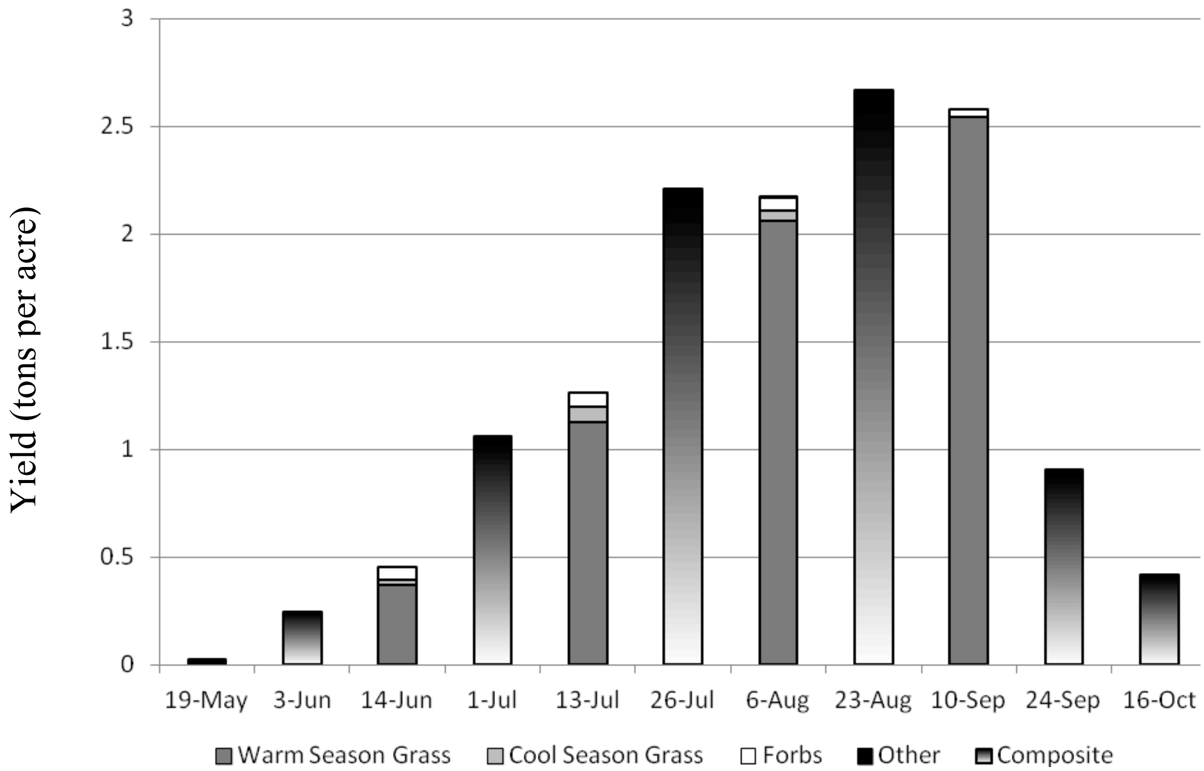

Yield (tons per acre)
3
2.5
2
1.5
1
0.5
0
19-May
3-Jun
14-Jun
1-Jul
13-Jul
26-Jul
6-Aug
23-Aug
10-Sep
24-Sep
16-Oct
Warm Season Grass
Cool Season Grass
Forbs
Other
Composite

Figure 7:

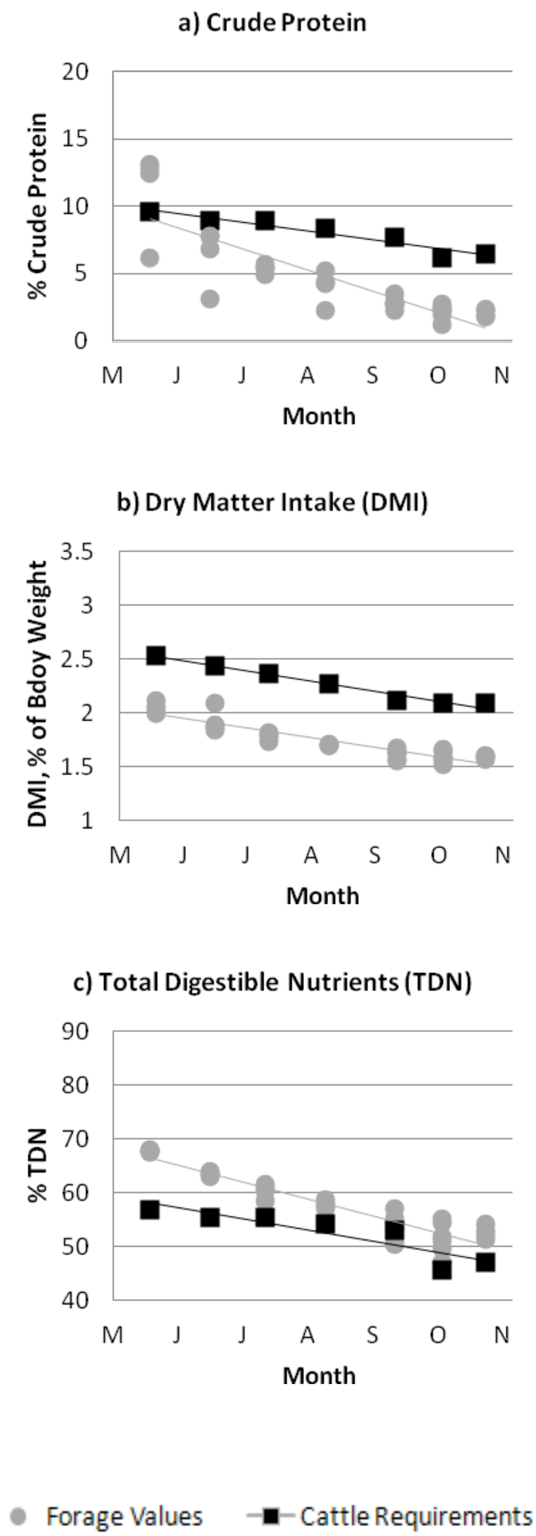

a) Crude Protein
% Crude Protein
20
15
10
5
0
M J J A S O N
Month
b) Dry Matter Intake (DMI)
DMI, % of Bdoy Weight
3.5
3
2.5
2
1.5
1
M J J A S O N
Month
c) Total Digestible Nutrients (TDN)
% TDN
90
80
70
60
50
40
M J J A S O N
Month
Forage Values
Cattle Requirements

Figure 8:

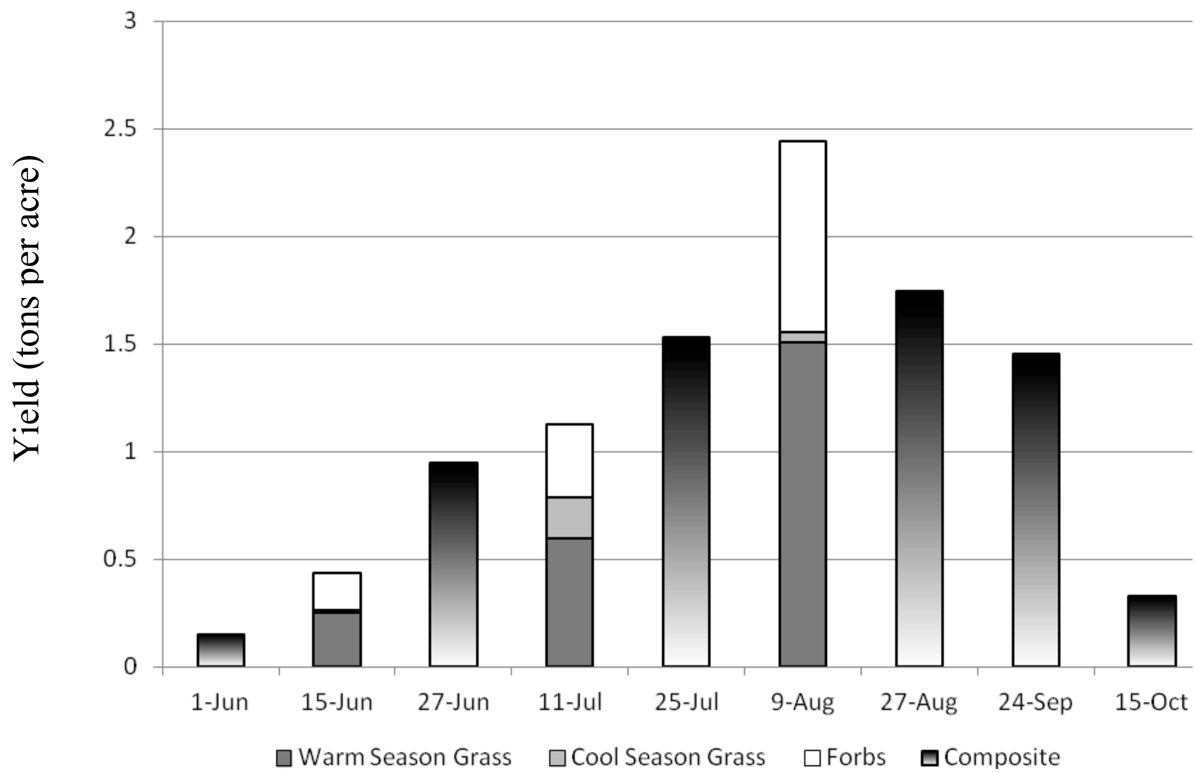
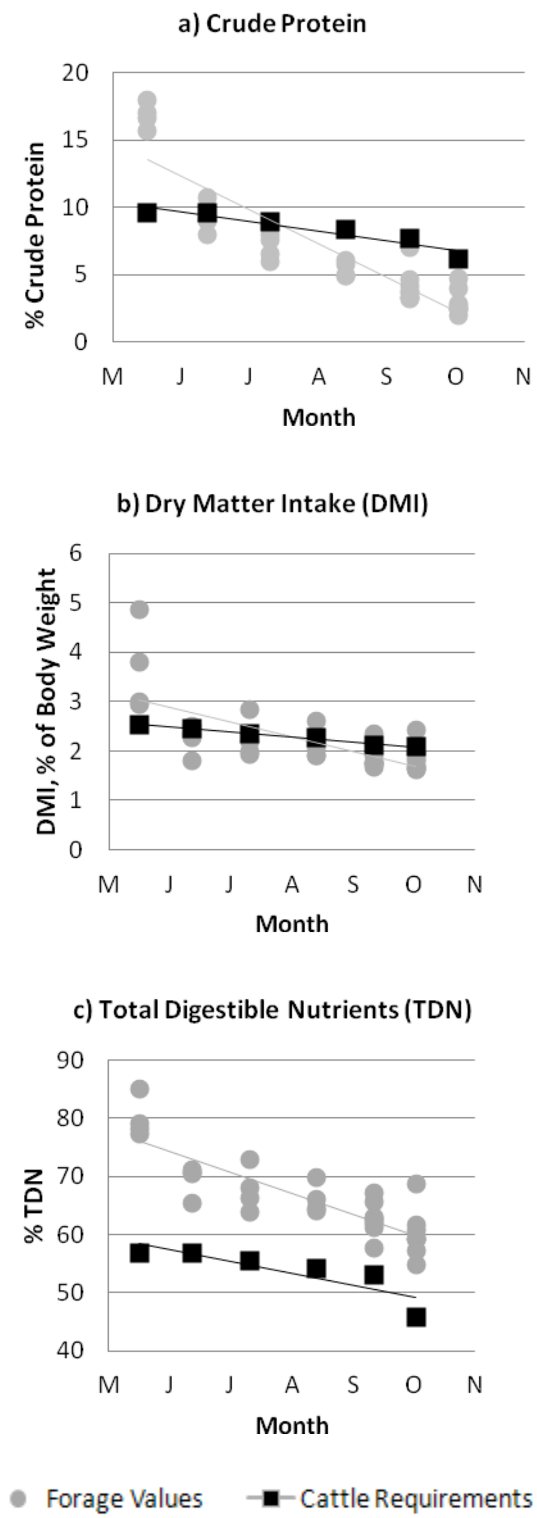

Yield (tons per acre)
3
2.5
2
1.5
1
0.5
0
1-Jun
15-Jun
27-Jun
11-Jul
25-Jul
9-Aug
27-Aug
24-Sep
15-Oct
Warm Season Grass
Cool Season Grass
Forbs
Composite

Figure 9:



a) Crude Protein
% Crude Protein
20
15
10
5
0
M J J A S O N
Month
b) Dry Matter Intake (DMI)
DMI, % of Body Weight
6
5
4
3
2
1
0
M J J A S O N
Month
c) Total Digestible Nutrients (TDN)
% TDN
90
80
70
60
50
40
M J J A S O N
Month
Forage Values
Cattle Requirements

Figure 10:

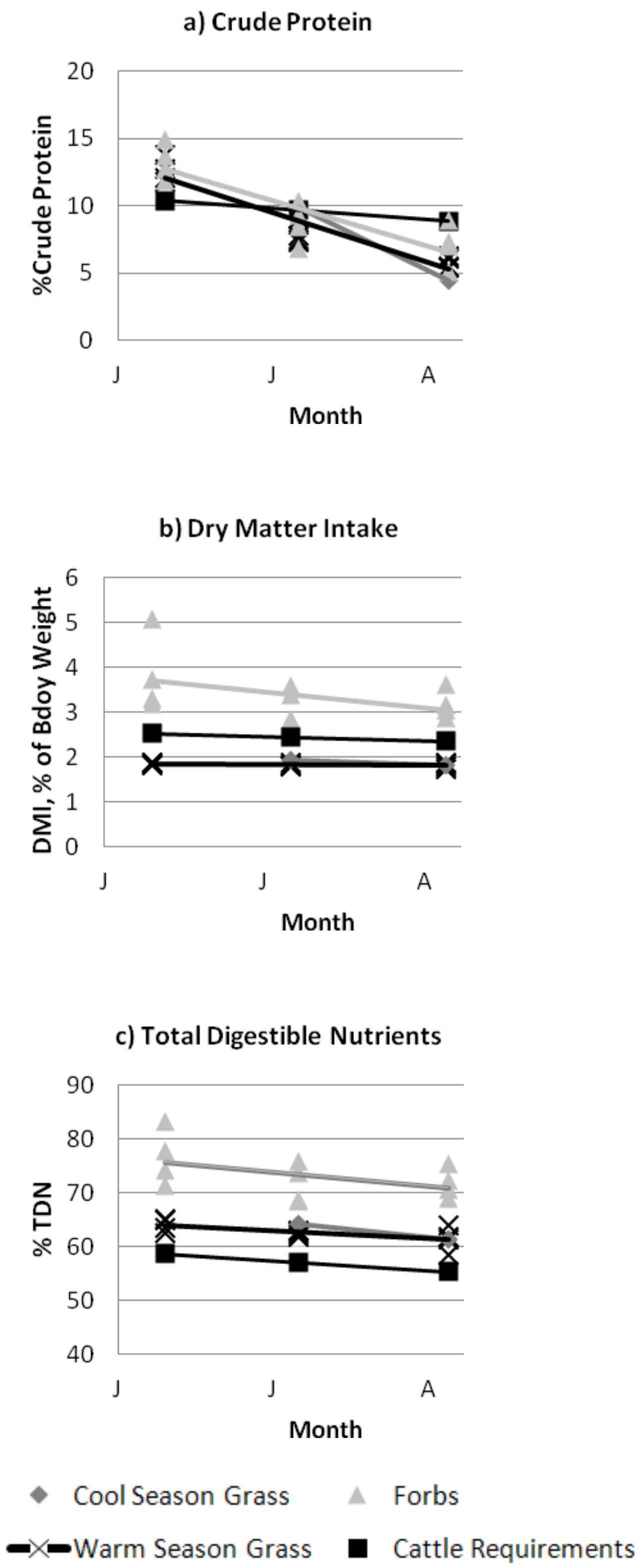

a) Crude Protein
20
15
10
5
0
%Crude Protein
J
J
A
Month
b) Dry Matter Intake
6
5
4
3
2
1
0
DMI, % of Bdoy Weight
J
J
A
Month
c) Total Digestible Nutrients
90
80
70
60
50
40
% TDN
J
J
A
Month
Cool Season Grass
Forbs
Warm Season Grass
Cattle Requirements

Figure 11:

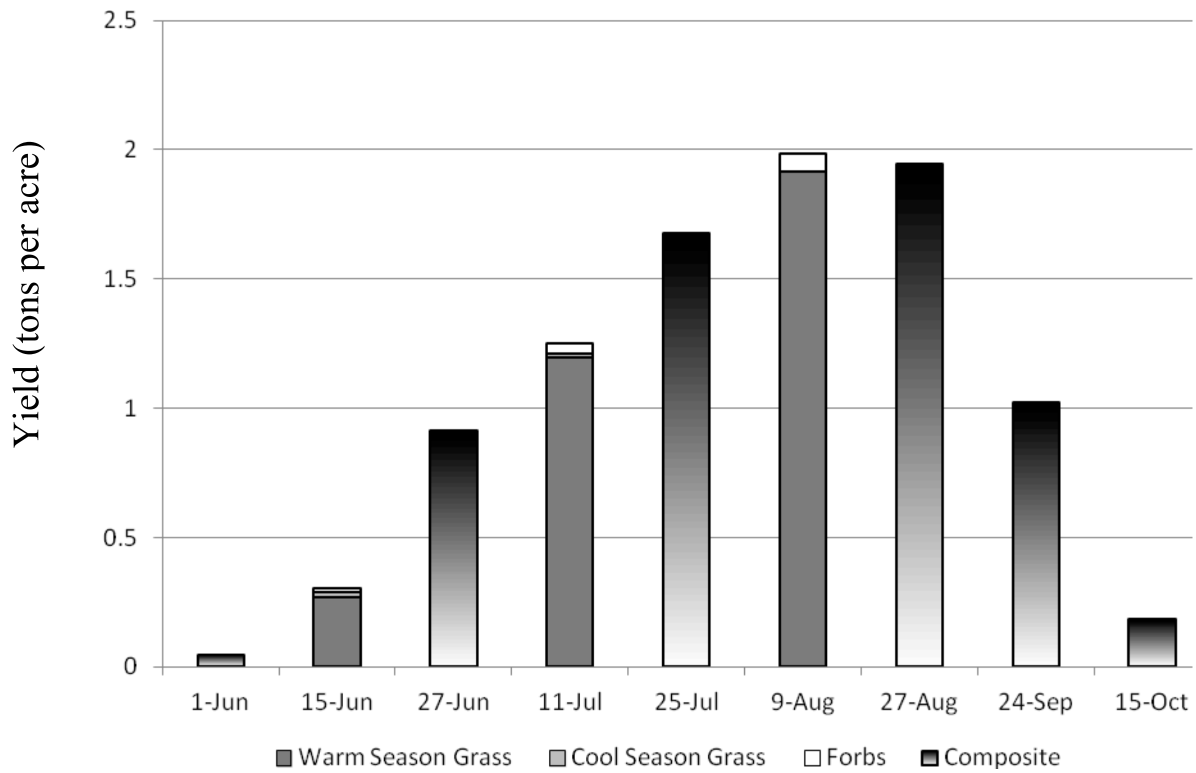
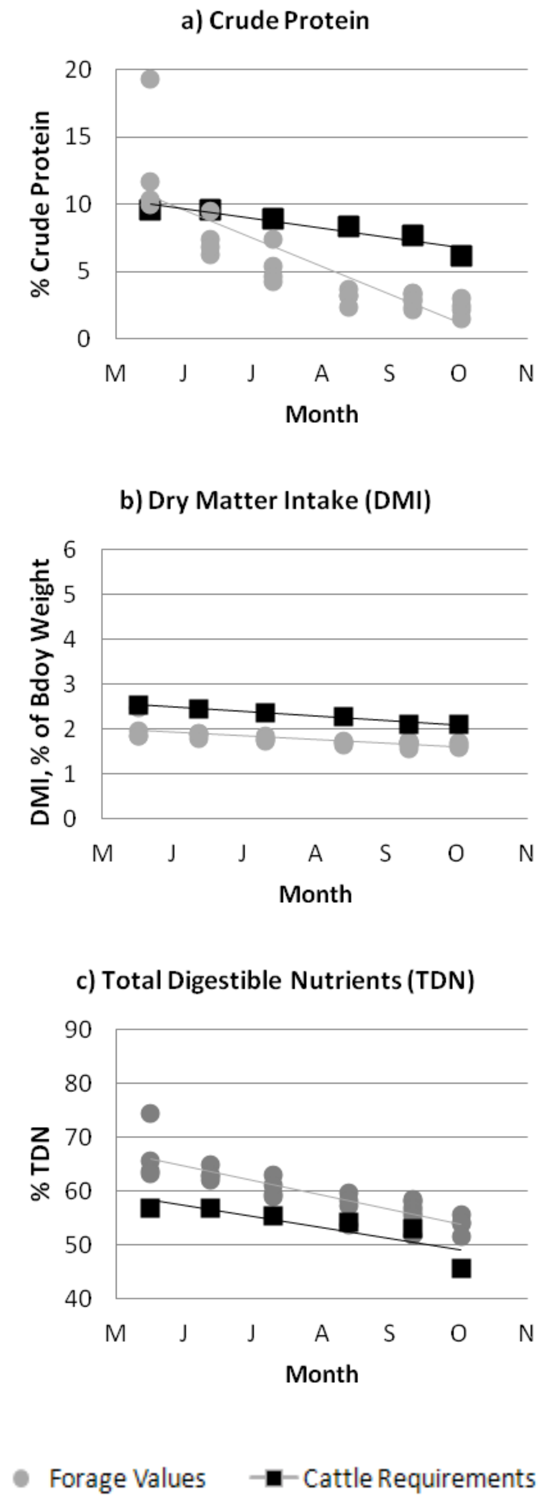

Yield (tons per acre)
2.5
2
1.5
1
0.5
0
1-Jun
15-Jun
27-Jun
11-Jul
25-Jul
9-Aug
27-Aug
24-Sep
15-Oct
Warm Season Grass
Cool Season Grass
Forbs
Composite

Figure 12:


a) Crude Protein
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20
15
10
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0
M J J A S O N
Month
b) Dry Matter Intake (DMI)
DMI, % of Bdoy Weight
6
5
4
3
2
1
0
M J J A S O N
Month
c) Total Digestible Nutrients (TDN)
% TDN
90
80
70
60
50
40
M J J A S O N
Month
Forage Values
Cattle Requirements

Chapter 4. Grazing native plants in Iowa: processes and profiles

A paper to be submitted as an *Iowa State University Extension Publication* after addition of photos and formatting

Rachael Cox and Mary Wiedenhoeft

Abstract

Grazing prairies presents a balanced approach to both agricultural production and natural resource conservation. Though a common forage base throughout the Western United States, native plants are not commonly used as a forage in Iowa, and therefore little information is available for making management decisions based on forage quality, forage yields, ecological impacts, and economic viability. While the majority of grazing systems in Iowa are focused on non-native cool season grasses, a handful of graziers and land managers are exploring native-plant-based grazing systems or including native plants in their operation. This paper highlights common approaches to including native plants in a grazing operation, economic and ecological considerations, and profiles of land managers and graziers who are integrating grazing into prairie management and/or farming operations.

Why graze prairies?

Prairies throughout Iowa serve multiple conservation purposes: 1) water quality, 2) erosion reduction, 3) wildlife habitat, 4) recreation, and 5) aesthetic value. These conservation purposes are often defined as ecosystem services: "the benefits that people obtain from ecosystems" (MEA 2005).

To assist in incorporating prairie onto farmland, various governmental programs, i.e. Conservation Reserve Program (CRP) and private organizations, i.e. Pheasants Forever, encourage planting prairie through cost-share or annual-payment-based programs. However, these payments may not be enough to maintain land in prairie when other crop production options are highly profitable.

Grazing livestock in conservation areas offers an alternative to separating 'productive land' from 'set-aside conservation' and may allow land managers or cattle graziers to generate profit from the land while maintaining or enhancing its conservation benefits. Though grazing in Iowa typically takes place on cool season grass and legume pastures, systems can be designed to include alternative forages such as prairie. Agronomic, economic, and environmental topics should be considered when designing a new management system on your land. This publication highlights some of these topics in relation to grazing prairies.

How can I incorporate prairies into my grazing operation?

In Iowa people are already using many strategies to incorporate prairie into their grazing operation, however many more options remain unexplored. A few categories of grazing include:

- **Grazing public lands:** Conservation organizations and public land managers are gaining interest in grazing as a management strategy on their prairie areas for a variety of reasons: income, controlling invasive species (i.e. buckthorn and honeysuckle), and diversifying disturbance management are a few.

- **Patch-burn or season-long grazing:** If interested in grazing larger areas of prairie, season-long grazing may be a consideration. Patch-burn grazing is one style of season-long grazing that focuses on burning a different segment of land representing a fraction (i.e. one-third) of land every year. In this system, animals have access to the whole land areas, burned and unburned, where they are likely to rotate following the new vegetation of recently burned areas (Kerby et al year?.). This encourages the animals to rotate grazing lands by following the best forage, and therefore creates a more diverse landscape with patches of burned, grazed, and undisturbed lands.

- **Prescribed grazing:** If you have smaller areas of prairie on your land or acres enrolled in CRP, you may consider prescribed grazing as a tool to better manage your prairie and gain some profit from the land at the same time. Prescribed grazing is a targeted practice focusing on certain areas during certain times to achieve management objectives. For example, if your entire land base has grass that is too thick for ground nesting birds, you may want to let cattle heavily graze at high density for a short period of time to clear the area for better wildlife habitat. Prescribed grazing can be used for many different management objectives but will typically be focused on smaller areas for shorter periods of time instead of a season-long approach.

- **Grazing native plants to rest cool season pastures:** Warm-season grasslands are more productive when cool-season grasslands enter a less productive period of growth during hot summer months. Graziers may consider planting or finding access to warm-season grasslands to use during July and August when cool-season pastures are less productive and at risk for overgrazing.

What are the economic risks and benefits?

Economic considerations are very important in deciding if and how to incorporate prairie into a grazing operation, for either a land manager or a livestock farmer. Expected costs and income are hard to predict and should be calculated for your individual scenario. However, a case study in Guthrie County, Iowa found that multiple grazing scenarios were less costly than feeding hay (Chapter 3, Cox-Ohde 2012). The case study compared feeding hay with three grazing scenarios: grazing your own CRP land, grazing at a conservation area paying a full rental rate, and grazing at a conservation area paying a reduced rental rate. All three grazing scenarios had lower costs than feeding hay.

What are the ecological risks and benefits?

Exclusion of grazing animals from prairie has been the typical management strategy for conservation, despite the fact that large grazing animals have been present on the tallgrass prairie landscape for thousands of years (Stebbins 1981). Bison (*Bos bison*), a large herbivore, has been identified as a keystone species in the tall grass prairie (Knapp et al. 1999). However, in most prairies in Iowa, grazing animals are not included. Prescribed fire and mowing are typical practices in Iowa for prairie management, and though grazing is encouraged, there is hesitance to use domestic livestock (Iowa Prairie Network 1994). Though cattle have somewhat different grazing behaviors than bison, they can play similar roles in conservation efforts combining grazing and fire (Fuhlendorf et al. 2010).

Based on a review of the literature related to grazing prairies and ecological impacts (Chapter 3, Cox-Ohde 2012), I expect grazing on prairie areas to increase plant and bird diversity if the entire prairie is not treated identically in space and time. Additionally, if grazing is moderate, and common practices of overgrazing or grazing along stream banks are avoided, grazed prairies can maintain water quality related ecosystem services similar to ungrazed prairies (Chapter 3, Cox-Ohde 2012).

The biggest risk to ecological health when including grazing on prairie reconstructions or restorations is overgrazing, which can be detrimental to plant communities, wildlife, and water quality. Another risk is applying the same management practice, such as grazing, at the same time of the season for many years in a row. This practice may cause native plant abundance to decline (Jackson 2010) or cause certain functional groups to dominate while others decline.

What are the agronomic risks and benefits?

Plant communities are dynamic, and in order to design grazing management strategies, forage availability and quality must be understood throughout the season, and among different plant functional groups. Forages change in quality and biomass availability throughout the season (Chapter 3, Cox Ohde 2012); however, these changes may not be known for the prairie area of interest for grazing. This lack of information makes it difficult to optimize animal production, which requires high yields and high quality forage. Without this information, graziers who choose to graze reconstructed grasslands take-on additional economic and animal performance risks.

Despite the risk of grazing in a system without detailed forage quality information, grazing native plants may provide benefits such as large amounts of forage biomass, productivity in variable weather conditions, and rest for cool season pastures.

Profiles: grazing native plants in Iowa

All data presented was collected following Iowa State University Institutional Review Board policies. The research proposal was determined exempt under federal human subject research policies. Despite the exempt status, each interview participant was provided with an informed consent document, which was signed, and returned along with a waiver approving use of names and locations in publications of the interview material.

Graziers

Though it is not a common practice, a small group of graziers in Iowa are exploring the use of native plants in their grazing systems as a part of the forage base or as the focus of their grazing operation. Below are some examples of how graziers are incorporating native plants, the benefits and challenges they have experienced, and what further questions they have. These profiles are intended to express a range and diversity of approaches to grazing native plants that may be useful in your operation.

Bob Jackson, Tall Grass Bison, Promise City, Iowa

Bob Jackson runs between 300-500 bison on 1000 acres, with pastures of unplowed prairie, reconstructed prairie, cool-season grasses, and woods. Pasture sizes range from 100-280 acres, and the bison are moved when they start to stand in big groups by the fences. Jackson started his grazing operation in 1982 with 19 bison in northern Iowa and later moved the operation to its current location in Promise City, near Lake Rathbun.

The focus of Jackson's grazing management is social-order grazing. Social order grazing keeps animals in family units, including matriarchic extended family units with higher nutritional needs and mature male groups that have lower nutritional needs. In a family group of up to 300 bison, there is a main matriarchic group, satellite matriarchic groups, and multiple groups of mature males. Social order grazing organizes ages and nutritional needs of bison to match the forage requirements, so the individuals with the highest nutritional need have access to the best quality forage.

Jackson butchers his bison in social-orders as well, harvesting whole matriarchic units at one time, including reproductive cows, yearlings, 2 year olds, mature cows, and grandmothers, which reduces the stress to the animals during the butchering process. Jackson harvests about 90 animals a year, whether for meat, or selling a family unit. In a family unit, individuals may range from 52 pounds hanging carcass weight to 1000 pounds, averaging around 450 pounds carcass weight per animal harvested. The animals are field slaughtered at the ranch and the meat is directly marketed as mostly quarters and halves.

Benefits: One of the primary benefits of social-order grazing is that older generations of grazing animals can pass on knowledge about eating habits that would otherwise be lost in typical grazing systems. These learned behaviors allow animals in social units to take advantage of the hundreds of prairie species that might otherwise be left alone by typical cattle herds that will select for grass-only diets.

Challenges and disadvantages: When grazing in social-order, a certain amount of land is needed for a complete family unit. Jackson's biggest challenge is his quantity of land, which limits him to only one social-order territory. According to Jackson, if he were able to have two territories and therefore two social groups, he would have more competition between bison and therefore more efficiency in production.

Research questions identified: Jackson identified a few research topics, first the nutritional value of non-traditional forages, such as native forbs, especially focusing on the value of the seedpods. He is also interested in how animals in different grazing systems exhibit different patterns of forage selectivity.

Suzanne Castello and Barney Bahrenfuse, B and B Farms, Grinnell, Iowa

Suzanne Castello and Barney Barenhouse farm 600 acres, 200 of crops and 400 of pasture, and raise beef cattle, pigs, sheep, and chickens, all of which spend some part of their lives on pasture. The cattle in the operation are managed using rotational grazing and the meat is direct-marketed. Castello and Bahrenfuse run 100 cows, and finish about three beef steers a month with the rest of the calves being sold. Shortly after Castello and Bahrenfuse began to rotationally graze two years ago, they began to see native plants returning to their pastures, including warm-season natives, some flowering forbs, and oak-seedlings, all of which they are happy to have.

Benefits: Castello identified the extensive root system and potential drought tolerance of native plants as an ecological benefit, one that could be an economic benefit during dry years.

Research questions identified: Though Castello and Bahrenfuse are experienced in managing rest periods for their cool-season grasses, they want more information on how to manage rest periods for native plants. Additionally, Castello is interested in what medicinal benefits native plants can provide to grazing cattle.

Bruce Carney, Maxwell, Iowa

Bruce Carney runs a grass-based cattle operation in Polk County, Iowa, grazing about 130 cow-calf pairs on 300 acres of cool-season pasture using rotational grazing strategies. Carney direct markets about 25-30 head of grass-finished beef a year through a local locker. Though none of his pastures are seeded with native plants, Carney incorporates native plants into his grazing operation by grazing public lands at Chichaqua Bottoms, a Polk County Conservation area.

In 2009-2011, Carney grazed his cattle continuously on 400 acres of lowland conservation area at Chichaqua. Due to flooding, native plant populations were lower than normal, but in 2011 there were more native sedges and forbs for cattle to graze. During each year the cattle grazed about 90 days, though management had to be flexible in order to stay compatible with the conservation goals of the land.

Benefits: In the time he kept his cattle at Chichaqua, most of his cows increased body-conditioning scores. He attributes some of his cattle's success to their winter management prior to grazing Chichaqua, which involved them having to look through snow to find forage. In his opinion, this experience made his cattle tougher, and allowed them to do well on the alternative forage source of native plants.

Grazing at Chicaqua was economically viable for Carney as he did not have to pay rent to graze 200 acres of pastures a few months out of the year, though he would still consider grazing the area with a reduced pasture rental rate. In addition to seeing an economic benefit, Carney noticed a decline in cottonwood seedlings at Chichaqua that coincided with the presence of his cattle.

Challenges and disadvantages: The biggest challenge Carney identified was infrastructure-related: investing in fencing and watering systems on areas with native plants. Investing in infrastructure is costly and interest in grazing native plants may depend on who is paying for the infrastructure – the grazier or the public land manager.

Research questions identified: Carney has further questions about how the native plants respond to grazing and how cattle grazing can mimic bison grazing to benefit the plants and the ecosystem.

Ray Bratsch-Prince, Ames Prairie Cattle Company, Ames, Iowa

Ray Bratsch-Prince has a cow-calf beef operation with 18 cattle in total, including heifers, cows, a bull, steers, and calves. He is early in his operation and hopes to finish his first three steers in 2012 and sell them through direct marketing. Bratsch-Prince uses rotational grazing, and moves his herd every day giving them about a quarter acre each day.

Bratsch-Prince has a few areas in his pastures that are made up of prairie plants that his landowner originally told him to avoid grazing. However, after a meeting with ecologist Tom Rosburg from Drake University, he found out that controlled grazing could benefit the land. Brastch-Prince now grazes the prairie areas in a similar paddock size and rotation as the rest of his pastures.

Benefits: Bratsch-Prince hasn't yet experienced economic benefits from incorporating native plants into his grazing operation, but he's already noticed an increase in native plants, and hopes he will soon begin to see more deer, pheasants, rabbits, and mice.

Research questions identified: Bratsch-Prince identified several research questions: are July and August good times to graze, can prairie pastures be grazed twice, and what is the appropriate height to graze prairie pastures?

Land Managers

A wide range of stakeholders in Iowa—including government agencies, not-for-profit organizations, private landowners, and farmers—manage conservation lands. Often conservation land managers do not own or operate grazing operations, so to use grazing as a management tool in prairie conservation areas, land managers often collaborate with graziers. Successful implementation requires communication between many stakeholder groups. The profiles below offer perspectives from land managers in Iowa that have been, or are currently involved in grazing projects on prairie areas.

Tolif Hunt, Former Director of Whiterock Conservancy, Coon Rapids, Iowa

Whiterock Conservancy is a land trust that was created in 2004, when the Garst Family started a gradual land gifting to the newly formed nonprofit conservation organization (Whiterock 2011). The mission of Whiterock Conservancy is to foster "a resilient and self-renewing Iowa landscape by integrating economics, social and ecological land management strategies and engaging the public via outdoor recreation and education" (Whiterock 2011). Whiterock Conservancy manages 5300 acres, including 4300 contiguous acres along the Raccoon River, which is split between 1,100 acres of pasture, 543 acres in row crop production, 1,000 acres in prairie or warm season grassland, 1,900 acres of timber, 260 acres of hay grass mix, 243 acres of wetland, and the remaining in miscellaneous categories.

The long-term goal for the reconstructed ecosystems is to manage them as a part of a working agricultural landscape, where agricultural lands are not separated in management from conservation lands. To accomplish this goal, Whiterock Conservancy plans to graze cattle on the reconstructed grasslands. Tolif Hunt, former director of Whiterock Conservancy, led much of the effort to include grazing as a management tool at Whiterock Conservancy. In 2011, Whiterock initiated their first grazing trials in reconstructed prairie areas and has plans to expand in 2012 and into the future.

Incorporating grazing into prairie management: Whiterock Conservancy grazed cattle in two ways in 2011. The first instance was a 2^{nd} year, 50 acre reconstructed prairie that was heavily invaded by cool-season grass, into which 30 cow-calf pairs were introduced for 30 days in May. The goal was to overgraze the cool-season grasses before the warm-season plants took off, in hopes of knocking them back and allowing the native plant species to thrive. The second grazing event involved 60 cow-calf pairs grazing in an oak savanna area in hopes of seeing some economic return from the piece of land. Cattle grazed there in November for about 10 days—a long enough time to take advantage of the forage, but short enough to leave some standing biomass for burning.

Benefits: Hunt is pleased with the results of grazing as a management strategy, and says they've gained some income from land that would have otherwise brought none. Grazing prairie areas has also given Whiterock Conservancy the opportunity to better manage their cool season pastures by resting those pastures while prairie areas are being grazed.

Relationship with graziers: In 2011, Whiterock Conservancy charged their standard rental rate of 80 cents per animal unit per day on their prairie grazing. They charged the standard rate under the assumption that if cattle were not getting sufficient high quality forage they would be moved to a different pasture and the producer would no longer pay rent on the land. Thus far, they have had a positive response from graziers, who were pleased with the safe conditions, secure perimeter fencing, and access to water.

Barriers to implementation: One of the main reasons Whiterock Conservancy has not grazed more areas and continues to hay pieces of land that would benefit from grazing is the cost of infrastructure to fence and provide water. Hunt also said that the amount of work involved makes it hard to justify moving 30 cattle to graze for only a couple of weeks on a prairie area.

Concerns: Using grazinggrazing, as an invasive species management tool will create different challenges than using fire. Hunt expressed his concerns with grazing cattle on prairie reconstructions: "you get them in there, it rains a whole bunch and it creates a heavy use area, suddenly in the middle of your beautifully restored prairie you got a place where you know thistle will take hold."

Research questions identified: Hunt is interested in further research that investigates the impact of fire and grazing on soil biological activity.

Loren Lown, Natural Resource Specialist, Polk County Conservation, Granger, Iowa

Loren Lown is a natural resource specialist at Polk County Conservation, the organization that manages Chichaqua Bottoms, a 7300-acre greenbelt bordering the Skunk River in Polk County. Chichaqua is made up of old oxbow channels, marshes, wetlands, and upland reconstructed and native prairies. The mission of Chichaqua Bottoms is "to restore vegetation and the hydrology to pre-settlement conditions, to manage for biodiversity, and to provide recreation that is compatible with the natural resources of the area." One method for managing biodiversity is to include grazing into the conservation management plan.

Incorporating grazing into prairie management: Much of Chichaqua Bottoms is wetland area and the areas in grassland were originally seeded to a low-diversity, warm-season grass mix by the NRCS. This provided very thick cover, which benefited certain groups of wildlife but does not provide the intermediate and open architecture required by many native species. As a way to better manage grassland structure and habitat, the land managers decided to use grazing as a management tool. Chichaqua's goal isn't to produce livestock, but to create diverse wildlife habitat for the most species.

Based on these ideas, Lown worked with scientists at Drake University to develop a grazing project at Chichaqua Bottoms. The fourth year of the project was 2011, and in 2012 scientists will study the impact of the grazing animals on the plant community. During the study, 100 cow-calf pairs from two neighboring farms grazed approximately 400 acres. Livestock were put onto the pasture progressively as more biomass became available and were removed before hunting season. In addition to the cattle grazing project, Chichaqua staff also worked with a goat farmer to graze oak savannas with the objective of clearing invasive species such as buckthorn and honeysuckle.

Benefits: Though the final results from the study at Chichaqua are not yet completed, the preliminary results have shown changes in small mammal and bird populations, including a new group of grassland bird species such as grasshopper sparrows, meadowlarks, and bobolinks that were not present prior to grazing.

In addition, the cattle body conditioning scores for the most part stayed the same or improved. Though the cattle weren't on a strict diet of native plants due to flooding—which caused an influx of annual weeds—they handled the non-traditional diet well.

Lown is hopeful that if their project shows that moderate, prescribed grazing provides benefit to the land, that the NRCS may consider it to be an allowable practice on other public and private WRP areas.

Relationship with graziers: Chichaqua Bottoms did not charge rent to the cattle producers who used their land. The organization provided the infrastructure to create a secure environment for the animals as their payment for the service they needed from the cattle: a prescribed disturbance. However, in the future, to make the system more economically viable, Lown may consider charging a grazing fee to help pay for the costs of maintaining infrastructure, though he never expects it to be a moneymaker.

Barriers to implementation: One of the biggest challenges Lown identified was the cost of fencing, water, and staff time invested in the project. Lown said that while he has also considered haying grassland areas, which would be low cost and could potentially even generate income, he thinks the grazing project will enable him to get the results he wants, even though it's much more expensive.

Research questions identified: Lown is interested in further research on the carrying capacity of Chichaqua for wildlife species of conservation concern and how grazed and ungrazed land may change the microclimates and microtopography of the land in such a way that would enhance the survival and expansion of those species.

Scott Moats, Director of Stewardship, The Nature Conservancy, Iowa

Scott Moats is the Director of Stewardship and Fire Manager of The Nature Conservancy in Iowa. The Nature Conservancy has nature preserves across Iowa, ranging from grasslands, watershed projects, and woodlands. At several Nature Conservancy preserves, grazing is used as a part of the management strategy, though most of the grazing efforts take place at Broken Kettle Grasslands, in the Loess Hills near Westfield, IA. Broken Kettle Grassland is 3000 acres and contains Iowa's largest remaining prairie.

Incorporating grazing into prairie management: When The Nature Conservancy acquired Broken Kettle, they removed the cattle that had been grazing the land, but soon realized they were losing certain wildlife species, especially species dependent on early succession ecosystems, i.e. recently burned or grazed prairies. To help with this problem, and to focus on the goal of plant diversity and rattlesnake populations, they reintroduced grazing, first using NRCS grazing recommendations, on 640 acres. The land managers quickly realized that NRCS grazing recommendations were too intense for the prairie area and scaled back stocking rates to better achieve management goals.

Broken Kettle land managers use patch burn grazing to manage the cattle, though they use more fencing then some patch burn operations for the sake of a research project. The stocking rate ranges from one cow-calf pair per acre to one pair per 12 acres and depends on the goal Moats and other land managers are trying to accomplish. Similar to prescribed fire, the management of prescribed grazing depends on timing, intensity, and frequency.

An important species at Broken Kettle are rattlesnakes, so grazing must be managed in a way that best suits these populations. Female rattlesnakes require good light penetration during pregnancy, depending on solar heat for the development of the baby. Grazing can provide optimal vegetation canopy, but requires correct timing to best suit the needs of both cattle and rattlesnakes.

Benefits: Though The Nature Conservancy spends some staff time and money maintaining the grazing system; overall Moats thinks the economics of the system are working for the organization. The goal of The Nature Conservancy is biodiversity, and Moats recognizes that grazing is an important tool to help them accomplish that goal.

Relationships with graziers: The Nature Conservancy has a small herd of bison, but rely on neighboring farmers with cattle herds to graze the grasslands. Cattle come onto their land around May 15 and are taken off around October 15. The arrangement is not a lease, as The Nature Conservancy regulates how many cattle are on different pieces of land. Graziers help with moving the animals accordingly, to achieve grazing goals, something they may not be responsible for on a typical lease.

Graziers pay per animal unit depending on the piece of land they are using. This system of rent may be more expensive for graziers as they cannot cheaply overstock and overgraze pastures, but at Broken Kettle managers strive for 60-70% forage utilization, so overstocking is not an option. In return for a higher cost, Moats said that graziers "get a better return with our system in terms of moisture retention and grass quality."

The Nature Conservancy pays for and takes care of the external fencing, but graziers are expected to provide and take care of interior fencing. In addition, they are required to maintain their own mineral, move the mineral around, and not leave the mineral too close to watering sources. The Nature Conservancy also provides the water, which comes from old livestock impoundments.

Barriers to implementation: One negative impact of grazing at Broken Kettle is the higher number of invasive plant species, though this has not caused a decline in native plant biodiversity. During hot summers, areas around watering sources are heavily impacted, allowing unwanted species to invade.

Another challenge Moats cited was working with cattle producers to move cattle when it was best for the nature preserve, but not necessarily ideal for a producer, who may be busy with other aspects of their farm operation. To help with this, The Nature Conservancy tries to give a couple weeks notice.

Research questions identified: Moats is curious about how the plant community composition and structure is changing and how grazing with bison year round would impact the cool season exotic plants. In addition, Moats would like to see research on the impact of grazing on wildlife species through a full calendar year.

Stan Buman, Agren Inc., Agricultural/Environmental Consultant, Carroll, Iowa

Stan Buman is a consultant working to combine agricultural production with environmental conservation. One way he addresses these issues is through pasture rest and revitalization to avoid overgrazing and associated environmental issues. To do this, he and his brother worked on a project to give graziers access to public prairies and grasslands in order to rest home pastures. The project took place at the Loess Hills State Forest with the support of a conservation innovation grant from NRCS.

Incorporating grazing into prairie management: Buman's role in the project was neither land manager nor grazier, but a facilitator of the stakeholders involved to make this project a success. Buman worked with a few graziers, including cow-calf and beef stock herds. During the project, they used a stocking rate of approximately six acres per animal unit. Buman said they kept the stocking rates conservative, as they were keeping the cattle on through the whole season. Additionally, he was responsible for making sure the prairie areas didn't get overgrazed.

Benefits: Though they didn't take official measurements, the ranchers that participated said their cattle did well, had good rates of gain, and one rancher participated for multiple years. Though originally nervous about the project due to the tendency for overgrazing in Iowa, the land managers at Loess Hills State Forest were also happy and continued the project after Buman's involvement ended. Buman also noted a change in bird species, seeing an increase in populations due to the change in diversity and structure of the grassland.

Relationships with graziers: Cattle producers rented the land on a per animal unit rate. The price was more affordable than typical rent as it was an incentive to help producers improve their own pastures. The grant received for the project paid for infrastructure investments, though the grant required matching funds, which were paid by the rental fees and the Loess Hills Alliance.

Barriers to implementation: Fencing has been a barrier in the project, as at one point the cattle got out and into a neighbors field.

Research questions identified: Buman is interested in the economics of grazing native plants, and how it can be economically viable to graze native plants, but also to create prairies where producers can take their cattle to revitalize their home pastures. Another research question of interest to Buman is the impact of grazing on wildlife populations given that grazing will provide a large amount of structural diversity to the grasslands.

Putting it all together – balancing economics and ecology

The interviews conducted highlight a wide range of experiences incorporating native plants into grazing operations in Iowa and in using grazing as a management tool for prairies and grasslands. Grasslands are dynamic and complicated ecosystems, and as land managers and farmers explore this management technique, we are sure to see varying results.

As some of the interviewees discussed, it is very difficult to place a value on the wildlife and diversity benefits that are likely to come from incorporating grazing as a management strategy on grasslands in Iowa. From a land manager's perspective, it may be easier to value the diversity and wildlife changes resulting from grazing, as success and financial viability is based on these measures. However, from a producer's perspective, without payments for ecosystem services, financial viability may not allow diversification into grazing native plants.

Individuals will need to consider the benefits, challenges, costs, and income that could result from various native plant grazing scenarios to find the one that best fits their system with the continued goal of improving ecosystem services on the Iowa landscape.

Recommendations for future research in grazing native plants

As conservation agencies can better justify the costs of prescribed grazing and profit from the benefits of increased wildlife and diversity, partnerships between conservation organizations and livestock producers may provide a more economically viable option than livestock producers adding prairie into their operation on their own or conservation organizations attempting to own and manage livestock.

In addition, as more research is completed demonstrating the ecosystem service benefits of grazing native plants, government conservation programs such as CRP, WRP, and EQIP may recognize the importance of grazing as a disturbance practice and may introduce more flexible policies that could allow more grazing to occur on these lands, thus making grazing native plants more economically viable.

Based on responses from the interviews, future research on this topic is needed in three areas: economic viability, wildlife and plant communities, and agronomic logistics. Specific topics of interest include the response of wildlife, native plants, and soil microorganisms to grazing; how grazing native plants can be done in an economically viable way for producers and conservation organizations; how high and how often to graze native plants; what the nutritional and medicinal benefits of non-traditional forbs are, especially looking at seed pods; and how plant selectivity differs in different grazing systems with native plants (i.e. social-order grazing).

Acknowledgements

I would like to express my gratitude to the farmers, ranchers, land managers, and consultants who took the time to participate in interviews for this project. It was an excellent way to learn more about the topic of my thesis and to better understand the workings of agriculture and conservation in Iowa.

I would like to thank the network of people interested in this topic for all the discussions that led to the formulation of ideas to create this publication. I am also grateful to this extensive group of people for connecting me with the farmers and land managers who participated in this project.

I would like to thank the undergraduate students in my lab and in the Soybean Entomology Lab for their help in transcribing the interviews. In addition, I would like to thank my major professors and my committee for allowing me to deviate briefly from my role as natural scientist to collect data from people.

Last, I would like to thank the USDA Sustainable Agriculture Research and Education organization for their support of this project through a graduate student grant. I am grateful for the opportunity to work with USDA SARE and to have completed such a project that would not have been possible without their support.

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Chapter 5. General conclusion

Summary of results and implications

This thesis highlighted two potential strategies for incorporating reconstructed native prairie plants into the Iowa landscape and into agricultural production systems as a way to increase ecosystems services and create a multifunctional landscape. Chapter two concluded that prairie strips are successful at attracting more soybean aphid predators than soybean fields; however, this increase in predators did not translate into increased biological control of soybean aphids. Neither an increase in quantity of prairie, nor proximity to prairie significantly impacted the level of biological control.

Though native plants tend to be the focus of recreating multifunctional landscapes, Chapter 2 demonstrated that native plants might not be the only or best way to do this, depending on what problem is being addressed. Our agricultural system is far removed from the native ecosystems of Iowa, and an attempt to balance the native ecosystems with agronomic production may not yield the desired ecosystems services that directly benefit agricultural production, such as biological control of insect pests. Further research exploring habitat manipulation to improve insect-derived ecosystem services should be studied at a landscape scale as well as the field scale.

Chapter 3 demonstrated that incorporating prairie into grazing operations can be both economically feasible and maintain or improve ecosystem services from prairie. Though, according to our study, forage quality of native plants does not provide adequate nutrition for cattle, further research on cattle performance may provide more insight into native plant quality than the clipped samples used in this study.

From the experiences of land managers and farmers highlighted in Chapter 4, I conclude that grazing native plants is a viable conservation strategy and a viable option for integrating into typical grazing operations in Iowa. From the interviews, we learned that there are many ways to integrate native plants into grazing operations and many more research questions to be answered in order to design best management practices. A wide range of approaches to grazing provided a wide range of benefits as well as challenges.

The implications of the studies reported in this thesis suggest that prairie may enhance the delivery of ecosystem services, but may not be universally applicable to all needed ecosystem services. As reported in Chapter 2, native plants are not successful in addressing every specific ecosystem service need on the landscape. To design a multifunctional landscape in Iowa, we must use multiple approaches in order to address specific ecological concerns while optimizing a wide variety of ecosystem services. This design will likely include native plants, but may also include other strategies to target specific problems such as exotic insect pests.

Acknowledgements

I would like to express my gratitude to my program of study committee who has guided me through the scientific process and mentored me through graduate school. I greatly appreciate their insight into science and life in general that they shared with me, and their openness to discussion. Thank you to Mary Wiedenhoeft who encouraged my independent thinking and excitement in approaching side projects. Thank you to Dr. Lisa Schulte Moore for taking me on part way through the process of graduate school and welcoming me into her lab, as well as a great deal of support in research design. Thank you to Matt O'Neal for pushing me to follow my interests and always taking me on for entomology projects though I have never been an official entomologist. I am very grateful for my committee's flexibility with my varied interest, including my sabbatical to Costa Rica to pursue a research project completely unrelated to my thesis (muchisisimas gracias por esta oportunidad!)

I would like to thank my fellow graduate students in all three lab groups I worked in for all the support and encouragement, for good discussions, and for help with field work and statistical analyses. I appreciate that I was welcomed into all three lab groups, even though I couldn't be a full member of any.

I am very grateful to all of the undergraduates who worked with me throughout the process of data collection and analysis, I could not have accomplished any of this without their hard work and dedication to a wide variety of slightly tedious activities like grinding many hundreds of plant samples for weeks on end.

Thank you to Jaci Severson, Melissa Stolt, Kelly Kyle, Charles Sauer, and Marti Steelman for all their help through the process of graduate school.

I would like to thank my friends and family for their support and encouragement in pursuing my educational goals, and for my husband Nick who put up with my constant jabbering about my ideas and my project, occasional help with field work, my many stressed out days and nights, and my lack of house cleaning and dish doing during the thesis writing process.